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PUBLIC PENSIONS AND STATE GOVERNMENT BORROWING COSTS

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ABSTRACT

I explore what U.S. state government bond prices imply about the relative recovery rates of pensioners and debtholders in a state default. Across U.S. states from 2005 to 2016, a one-standard-deviation increase in the ratio of unfunded pension liabilities to GDP is associated with a 27–32 basis point increase in bond spreads over the Treasury rate. Unfunded pensions cost U.S. states over $2 billion in lost bond issuance proceeds in 2016. Event study exercises examining the reactions of bond spreads to a pension reform in Illinois provide evidence that the effect of unfunded pension liabilities on bond spreads is causal. The effect of unfunded pension liabilities on bond spreads is stronger in states where pensioners are likely to have higher bargaining power or legal protection in a default. These facts are consistent with predictions from a structural model of municipal government credit, and model estimates reveal substantial cross-sectional variation in investor perceptions of pension seniority. These perceptions are related to state-level political and legal factors which may affect recovery rates of pensioners in a default.

CHAPTER 1

PUBLIC PENSIONS AND STATE GOVERNMENT BORROWING COSTS

1.1 Introduction

The U.S. municipal bond market is a $3.8 trillion capital market that finances two thirds of infrastructure projects in the U.S. along with other activities for more than 50,000 state and local governments.[1] State and local governments spent over $119 billion in debt interest expenses in 2016.[2] Therefore, borrowing costs and their determinants are of critical concern to both municipal policymakers and their constituents. State governments, which issue over one third of all municipal debt, also have another large liability on their balance sheets in the form of pension obligations. Researchers have highlighted that liabilities are often larger than reported, which could lead to fiscal issues for state governments down the road ([27]). Less attention, however, has been paid to quantifying how public pension liabilities are already affecting default risk, and consequently state borrowing costs. Moreover, little is known about how states would settle competing claims by pensioners and debtholders in a default.

Although some have argued that pension liabilities are wholly the most senior liability for a state government, others claim this is not necessarily the case ([10]). In the Detroit bankruptcy, for example, pensioners agreed to a cut in promised obligations, even though bondholders were not completely wiped out. Unlike the situation in Detroit, state government default is an event without a legal framework or modern-day precedent in the U.S. Therefore, the structure for how a state default would play out, both legally and practically, is quite uncertain. In practice, the relative seniority of pension and bonded liabilities may depend on political and legal factors specific to each state. Current state bond prices should

1. "Muni Facts," MSRB 2019.

2. "State and Local Expenditure," Urban Institute

contain market expectations for how competing claims between pensioners and debtholders would be settled in default.

In this paper, I explore what U.S. state bond prices imply about the relative recovery rates of pensioners and debtholders in a state default. I focus on state bonds because of the uncertainty surrounding state government default. I ask how much of the cross-state variation in borrowing costs, as measured by the spread of bond yields over Treasuries, is due to differences in unfunded pension liabilities? Moreover, I explore how the relationship between pension funding and borrowing costs interacts with the political economy of public pensions, especially with cross-sectional differences in the perceived seniority of pension liabilities across states. As part of this analysis, I use observed state bond spreads over the Treasury rate to estimate the amount of unfunded pension liabilities which are senior to general obligation debts. I then examine how estimates of seniority vary with political and legal factors in the cross-section of states.

I first develop a Merton-style structural model for pricing government debt, which provides testable implications for the relationship between pension liabilities, bonded debt, and pension seniority. I innovate on the standard [20] model by including three tranches of debt: a senior pension claim, a bond claim, and a junior pension claim. The fraction of the total pension obligation that is senior to bonded debt is governed by a variable, ϕ, which I refer to as the pension seniority parameter. In the model, spreads are increasing in both the level of pension liabilities, and also the seniority of those liabilities relative to bonded debt. The model also predicts that pension liabilities have a stronger effect on bond spreads in states where those liabilities are relatively more senior.

I use reduced-form cross-sectional regressions to test these predictions, and I find a robust and statistically significant relationship between the level of unfunded pension liabilities and state bond spreads. A one-standard-deviation difference in the unfunded pension liability to GDP ratio for a state is associated with a $27 - 32$ basis point higher spread, about $16 - 20\%$ of the total average spread in my sample. In a difference-in-difference event study exercise exploring the reactions to pension reform legislation I provide evidence that this relationship is causal. Following the passage of pension reform legislation in Illinois in 2013, state bond spreads decreased significantly, when compared to spread movements in other states. Meanwhile, spreads increased significantly when that legislation was overturned by the state Supreme Court in 2015. I also show that unfunded pension liabilities have a larger effect on bonds with longer maturities, which implies unfunded liabilities are more likely to effect state solvency in ten to twenty years.

Next, I show the effect of unfunded pensions liabilities on borrowing costs is significantly stronger in states with stronger legal protections for pension liabilities. These results imply markets are pricing off-balance-sheet pension risks, and that markets believe legal protections matter for their implied seniority in the event of a default. Additionally, I find the effect of unfunded pension liabilities on borrowing costs is stronger in states with stronger union presence. Increased bargaining power may increase the "seniority" of pension liabilities in the event of a fiscal crisis. With these results, I provide evidence that pension liability seniority in the event of a default is not a certain matter. The relative recovery by both pensioners and debtholders will likely be the result of a state-specific negotiation process, and markets appear to be factoring this possibility in to municipal bond prices. These results are consistent with the qualitative predictions of my model.

Finally, I estimate the model using observed bond spreads to determine the implied seniority of pension liabilities. For each state-year I estimate the pension seniority parameter, ϕ, which represents the fraction of unfunded pension liabilities which are senior to bonded debt in the model. Model estimates show markets do not necessarily perceive pension liabilities as wholly senior to bonded debt (i.e. $\hat{\phi} < 1$), and that substantial cross-sectional variation exists in investor perceptions of pension seniority. According to the model, on average, observed spreads are consistent with 61% of unfunded pension liabilities being senior to general obligation debts. The cross-sectional variation in implied seniority is in line with my reduced-form political and legal variables. I find a positive and statistically significant relationship between estimated pension seniority parameters and explicit state-level constitutional protections for pension liabilities along with public union membership. These results imply that pension liabilities are not necessarily the most sacrosanct liability on a government's balance sheet. Moreover, in a state default, political and legal factors will likely have a significant role in determining relative recovery rates.

My study presents a unique investigation of what observed state bond spreads imply about the political process between pensioners and debtholders that would occur in the event of a state default. These findings are qualitatively and quantitatively meaningful for policymakers, because they describe the effect of fiscal policies on *current* borrowing costs. Also, my results suggest the determination of relative recovery by pensioners and debtholders in a potential default is likely more nuanced than some have claimed. Policymakers and constituents must understand this nuance when assessing the likelihood that states will be able to meet promised pension obligations.

1.1.1 Literature Review

My paper bridges the gap between the literature on public pension funding and the literature on the determinants of municipal bond yields. More broadly, my paper contributes to the literature exploring the effects of political uncertainty on asset prices. The majority of previous research on determinants of municipal bond yields focuses on either liquidity or the incorporation of tax exemptions into prices. However, recent work by [32] shows default risk, not liquidity, is the main driver of municipal (including state) bond yields. An obvious question arising from this finding is: What drives cross-sectional and time-series variation in municipal default risk?[3] My results suggest unfunded pensions are a significant contributor to state bond risk, and therefore borrowing costs. This fact is consistent with [1] who show state-level factors drive a significant portion of variation in state-level credit default swaps.

3. No comprehensive study of the determinants of municipal bond yields and default risk has been performed since [17].

Part of this literature focuses on the effects of political factors on municipal bond prices. For example, [7], [13], [14], and [30] explore how variables such as corruption, local newspaper presence, and balanced-budget amendments affect bond yields. I contribute to this literature by investigating the interplay between political economy, pension funding, and municipal debt. I show that unfunded pension liabilities do have a significant effect on debt pricing. The effect could be related to the finding in [8], who find that states with older populations have higher bond yields. Although, I also find this relationship varies with other state-level political and legal factors.

I also contribute to the literature on public pension liabilities. Recent research by [26] and [27] exposes the widespread use of poor accounting practices for public pensions. They argue that outstanding liabilities are much larger than commonly reported, due to the use of poor discount rate assumptions. These papers, however, make stark assumptions about the perceived seniority of pension liabilities (i.e. assuming they are risk-free or have the same seniority as general obligation debt). [6] highlight the fact that many states have constitutional protections for state pensions, and argue that these protections make them wholly senior to bonded debts. [27] cite this work in using a risk-free rate to discount pension liabilities. [24] also effectively assumes that pension liabilities are non-defaultable in his model of public pensions and municipal insolvency. In my paper, I move this literature forward by taking seriously the idea that pension seniority may be the result of a political process between pensioners and bondholders. I use observed bond spreads to uncover what markets imply about the actual seniority structure of these liabilities.

There is a small literature looking at specific relationships between public pensions and state borrowing costs. [22] find a small reduced-form relationship between bond yields and pension contributions from 2005 to 2009. Meanwhile, [28] use cross-sectional differences in pension asset returns during the financial crisis to provide evidence of a sovereign default channel in state bond markets. My event study exercises provide further evidence of a causal channel between pension funding and state bond yields. In considering other fiscal variables, I am able to control for state and time-level trends that could confound with pension funding - an issue discussed by [25]. I provide a more expansive look into the relationship between pension funding and debt spreads over a longer period. Moreover, I focus on the interaction between funding and the political economy of pensions on bond yields.

More broadly, my paper relates to the literature on political uncertainty and asset prices. [29] develop a general equilibrium model in which stock prices react to political news. [19] provide empirical evidence that this uncertainty is priced in options markets. Meanwhile, [15] study municipal bond yields around gubernatorial elections. Consistent with the mechanism in [29], they find an increase in spreads around elections, which they argue are times of greater political uncertainty. In concurrent work ([5]), I show that legal uncertainty may play an important role in state bond prices. In this paper, I explore the political and legal uncertainty surrounding state government default and investigate how it affects municipal bond prices.

The remainder of the paper is laid out as follows. First, in Section 1.2, I provide background information on state debt markets and public pensions. Next, in Section 1.2, I present a structural Merton-style model for municipal debt pricing and derive three main empirical predictions. In Section 1.3, I present the data for my main analyses. Next, in Section 1.4, I perform my main reduced-form regression analyses, exploring the relationship between pension funding, and state borrowing costs. Following that, in Section 1.5, I explore how the effect of unfunded pension liabilities on borrowing costs varies with state-level political and legal factors. Finally, I provide results from the structural estimation of my model in Section 1.6. Section 1.7 concludes.

1.2 Background on State Bonds, Default, and Public Pensions

In this section, I provide background information on state bonds, default, and public pensions. First, I describe basic characteristics of state debt markets. Next, I discuss the uncertainty surrounding state government default. Finally, I describe how public pension liabilities may affect default risk, and therefore state bond prices. This background information motivates the structure of the model in the following section.

Municipal governments issue bonds primarily to fund capital expenditures such as roads, schools, hospitals, and even sports stadiums. The types of governments that issue these bonds are numerous. States, counties, cities, towns, school districts, water districts, and other municipal entities issue municipal debt. A primary advantage of holding municipal bonds is that the income received from interest payments is usually tax-exempt at the federal, state, and local level. Therefore, bonds are generally held by high-net-worth individuals who can benefit most from this exemption. [2] show that 42% of municipal debt is held by the top 0.5% of individuals by wealth.[4] Over 50% of municipal debt is held by retail investors.[5] The yields on municipal bonds are generally lower than a corporate bond with similar credit risk because investors require a lower return due to the tax-exemptions.[6] Indeed, the purpose of these exemptions is to give access to cheaper credit for municipal governments.

In general, two types of bonds are issued by state and local governments: general obligation (GO) bonds, and revenue bonds. GO bonds are backed by the full faith and credit of the underlying government. That is, the municipalities' ability to raise tax revenue serves as collateral for the bond. Meanwhile, revenue bonds are tied to specific capital projects. Proceeds from these projects (e.g., tolls from a road) are used to make interest payments.

I focus on state bonds as opposed to a broader set of municipalities, partly for data reasons. Pension funding data are available for nearly the universe of state plans, but not for the world of municipalities. Additionally, collecting fiscal information for 50 states is more feasible than collecting it for the larger universe of municipalities. The main reason, however, I focus on state bonds is the uncertainty around default. As I discuss below, the legal and

4. The tax-exemption is only valid if an owner is a resident of the state where the bond was issued. Therefore, there is a natural market segmentation in municipal markets.

5. "Trends in Municipal Bonds," MSRB. 2019

6. [21] shows that in perfect capital markets the yield on a tax-exempt bond should equal one minus the tax rate, times the yield on a taxable bond of identical credit quality. [37] shows that this relationship does not necessarily hold empirically, which has been referred to as the "muni bond puzzle."

practical structure for state default is almost non-existent, which leads to a great deal of uncertainty regarding how relative claims by pensioners and bondholders would be sorted out. Municipalities face less uncertainty, because they have access to Chapter 9 bankruptcy. Part of the goal of this paper is to use market prices to resolve some of that uncertainty or at least discern some information about market expectations for how a state default would play out.

Current observed spreads suggest present default probabilities may be higher than historical figures, despite the fact that state government default is extremely rare in the U.S.[7] No state has defaulted since Arkansas during the Great Depression and other than a handful of defaults during the Civil War, instances of state government default are almost nonexistent. Even in the case of Arkansas, debtholders were eventually made whole. Given that ratios of state government debt to GDP are much lower than most sovereigns (even when including pension liabilities), along with the wide taxing authority of states, the prospect of actual default may appear unlikely. However, fiscal issues, particularly with unfunded pension liabilities, may change this perception and contribute to higher borrowing costs.

Even in the case of an insolvency, state default currently has no legal framework. States are sovereign under the U.S. Constitution and therefore cannot be sued, which rules out the possibility of bankruptcy hearings. Although, some legal scholars have argued for the need for such a structure (see, e.g., [35]). Nevertheless, sovereigns (e.g., Argentina) have defaulted in the past and not been shut out of markets indefinitely. Recent events in Puerto Rico suggest that given a dire enough fiscal crisis, the U.S. government may be willing to create legal structures to facilitate a default. Therefore, factors such as legal protections and relative bargaining power, which may affect recovery in a default, may also affect current bond spreads.

While state government defaults are extremely rare, municipal defaults do occur. Although no legal structure for state bankruptcy exists, Chapter 9 of the bankruptcy code

7. See [32] for a discussion of physical and risk-neutral default probabilities implied by state bond yields.

deals explicitly with municipal bankruptcy.[8] The majority of recent default crises have been triggered by idiosyncratic issues, which makes generalizing their structure to a potential state default difficult.[9] In the majority of these defaults, conflicts have arisen between debtholders and pensioners. In most cases, pension liabilities have been protected relative to bondholder claims, although full recovery has not been universal. Negotiations, such as those in the Detroit bankruptcy, may set a blueprint for how different claims may be handled in a state default. In [5], I show that state bond yields react to legal events related to bankruptcy in Puerto Rico, suggesting markets see these decisions as setting a precedent for what would occur in a state default.

Ultimately, both sovereigns and municipalities have defaulted on debt obligations, so we have no reason to rule out the possibility of a state default. Given this possibility, researchers must understand what drives default risk in municipal markets. A better understanding of the determinants of risk, and how they are related to state-level political and legal factors will provide information on market expectations for the likely structure of a state bankruptcy. It is important for policymakers to understand this fact as they must deal with higher borrowing costs now resulting from higher default risk.

In this paper, when I discuss default, I refer to default on bonded debt. Bond yields, and their spreads over Treasuries, are tied to default events on the underlying bond, not potential missed pension payments. Nevertheless, pension liabilities are a significant payment obligation for a state government. What is unclear in practice, is the relative seniority of bonded debt as compared to that of pension liabilities. [34] notes that the legal priority of bonded versus pension debt is uncertain in municipal bankruptcies, and would be in the case of state issues. Outcomes for bondholders and pension holders are generally municipal specific, and depend on court preferences and the relative bargaining power of the two parties. I investigate what municipal bond spreads imply about the relative seniority of each

8. [14] discuss the role of Chapter 9 protections at the state level on local municipal bond yields.

9. In recent years we've seen municipal bankruptcies in the municipalities of Bridgeport, CT, Central Falls, RI, Detroit, MI and Jefferson County, AL. For more discussion of municipal bankruptcy, see [36].

obligation in state debt markets. Even if bonded debt is more senior, pension payments divert resources that could otherwise be used to service debt, thus leading to higher default probabilities, or losses given default. That channel would also result in higher borrowing costs for states with larger unfunded pension liabilities.

One natural question in this context is what role the federal government might play in a state bankruptcy? The federal government does not have a track record of bailing out state governments. For example the federal government did not provide any assistance to states that went through bankruptcies in the 1800s ([31]). Moreover, the federal government has not intervened in more recent municipal bankruptcies such as Detroit and Orange County. That being said, in dire fiscal crises such as that in Puerto Rico the federal government has set a precedent for intervention ([5]). Meanwhile, recent policies around the COVID-19 virus have shown a willingness to prop-up municipal debt markets in unprecedented times. If one believes bailouts are a real possibility, one would expect to see low yields on municipal debt given low default probabilities. The fact that this is not the case, along with past precedent makes it unlikely that bailouts are seen as likely by investors. Moreover, for bailouts to significantly bias my main results would necessitate that bailouts probabilities vary cross-sectionally across states. While one might argue that in a given state of the political economy, I abstract from it in this paper. That being said, using municipal bond prices as a tool for understanding the likelihood of future bailouts could be fruitful ground for future work.

Considerable uncertainty surrounds the idea of state default. In this paper, I highlight that uncertainty and also take steps to resolve it. To that end, I use observed market prices (bond spreads over Treasuries) to explore the relationships between the political economy of public pensions and borrowing costs. I take seriously the notion that a state could default and that the relative pecking order of bond and pension liabilities in a default is not certain. I aim to provide some qualitative and quantitative clarity on what markets imply about these relationships and also how a state default might play out.

1.2 Structural Model for Municipal Debt

To explore the relationship between pension liabilities and state government debt spreads, I propose a structural contingent claims model of state governments' balance sheets and debt prices. The model provides testable cross-sectional predictions for how pension liabilities and pension debt seniority will affect debt prices (and spreads). In this section, I derive those qualitative predictions which I test empirically in Section 1.4.

1.2.1 Model Description

The model is an adaptation of the [20] model for corporate debt (henceforth referred to as the Merton model). As such, the [4] no-arbitrage option pricing methodology can be used for calculating the value of government debts. I innovate on the model by including three classes of debt: a senior pension claim, a bonded claim, and a junior pension claim.[10] The adaptation also draws on the sovereign contingent claims analysis of [16].

A government's net fiscal asset, V_A, is given as the expected present value of all future government revenues minus the expected present value of all future government expenditures (i.e., the net present value of all future government surpluses). V_A evolves as a geometric Brownian motion with drift μ and volatility σ_A:

$$dV_A = \mu V_A dt + \sigma_A V_A dW_t \tag{1.1}$$

I assume a government has bonded debt obligations, B_D, due at date T. The government also has pension liabilities, B_P, due at date T. I assume a fraction, ϕ, of these pension liabilities are senior to the bonded debt. Meanwhile, the remaining $(1 - \phi)$ fraction of the pension liabilities are junior to the bonded debt. I refer to ϕ as a "seniority" parameter because it dictates the relative seniority of the pension debt as opposed to the bonded debt.

10. [3] derived prices in a modified Merton model with two classes of debt. [33] uses this methodology to compare the prices of bank loans to bonded debt.

This parameter can also be thought of as a relative recovery rate for pension liabilities. Four potential outcomes are possible at date T:

1. $V_A > B_D + B_P$: All government liabilities are paid in full. The remaining asset value $(V_A - B_D - B_P)$ can be thought of as the government's "equity" value.

2. $B_D + \phi B_P < V_A < B_P + B_D$: Government pays all bonded obligations and defaults on only $\frac{V_A - B_D}{B_P}$ of pension obligations.

3. $\phi B_P < V_A < B_D + \phi B_P$: Government pays ϕ percentage of the pension liabilities but only pays back $\frac{V_A - \phi B_P}{B_D}$ of the bonded obligations.

4. $V_A < \phi B_P$: Government defaults on all bonded obligations and only pays back $\frac{V_A}{B_P}$ of pension liabilities.

I present a graphical sketch of the model in Figure 1.1. The dotted blue lines represent the default thresholds as discussed above. The red curve is the distribution of asset values at maturity. For a given realization of V_A at T, all debts below that value will be paid, while, any obligation above the realization will not be paid. Meanwhile, the sum of the distribution below any value at T represents the probability of default for that amount of total debt. For example, ϕB_P represents the "senior" pension debt. Therefore, the sum of the distribution below this line represents the probability that the government defaults on all debt *except* the senior pension claim.

Given this set up, the value of the bonded debt, V_D, can be viewed as the difference between two call options on the government's net fiscal asset. The bonded debt begins paying off if V_A is greater than the "strike price" of ϕB_P, the amount of senior pension liabilities, but stops paying off if the value is greater than $\phi B_P + B_D$.[11] Under Black-Scholes assumptions, the current market value of debt is given by:

11. Put-call parity leads to a valuation of debt that is equal to the difference between two put options.

Figure 1.1: Model Sketch

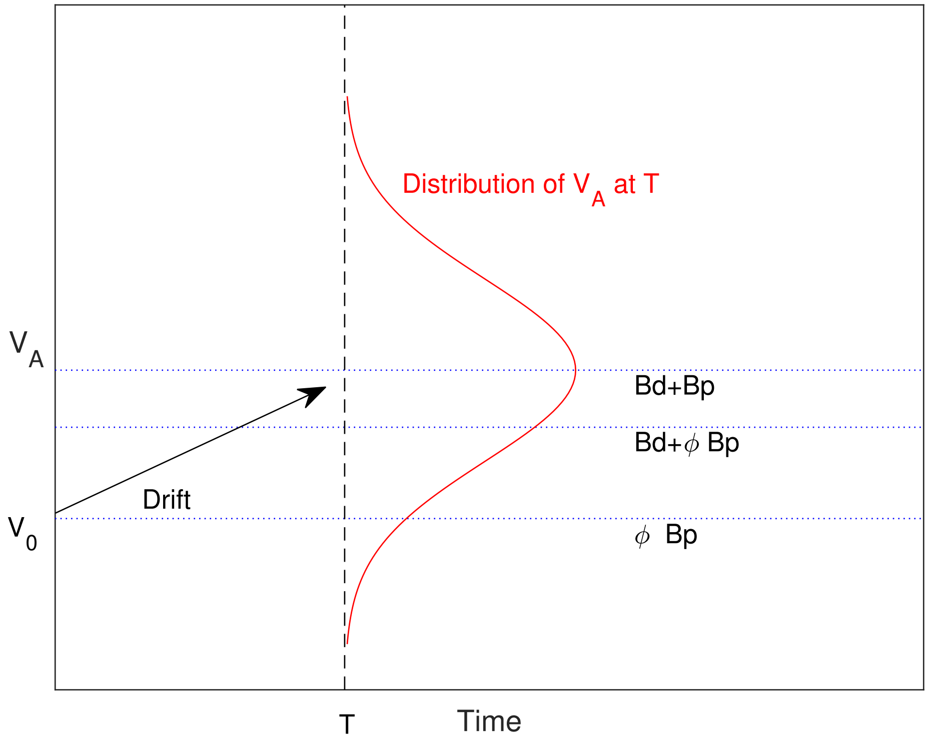

Figure 1.1 presents a graphical sketch of the structural contingent claims model of government debt. V_A represents the government asset value. B_D is bonded debt obligation due at T. B_P is the pension liability due at T. ϕ is the fraction of the pension liability which is "senior" to the bonded obligation. The red distribution represents the distribution of asset values at maturity, V_T.

$$V_D = \left(V_A N(d_1^{\phi}) - \phi B_P e^{-r_f T} N(d_2^{\phi})\right) - \left(V_A N(d_1) - (\phi B_P + B_D)\, e^{-r_f T} N(d_2)\right) \quad (1.2)$$

where,

$$\begin{aligned}
d_1^{\phi} =& \frac{1}{\sigma_A \sqrt{T}} \left(\ln\left(\frac{V_A}{\phi B_P}\right) + \left(r_f + \sigma_A^2/2\right) T\right) \\
d_2^{\phi} =& d_1^{\phi} - \sigma_A \sqrt{T} \\
d_1 =& \frac{1}{\sigma_A \sqrt{T}} \left(\ln\left(\frac{V_A}{\phi B_P + B_D}\right) + \left(r_f + \sigma_A^2/2\right) T\right) \\
d_2 =& d_1 - \sigma_A \sqrt{T}
\end{aligned}$$

and r_f denotes the risk free rate.

The credit spread on bonded debt can be written as:

$$s_D = -\frac{1}{T}\ln\left(1 - \frac{(P_{D+P} - P_P)}{(B_D)e^{-r_f T}}\right) \tag{1.3}$$

where P_{D+P} is the value of the put option on all government bonded debt and the senior pension liability, and P_P is the value of a put option on only the senior pension liabilities:

$$P_P = \phi B_P e^{-r_f T} N(-d_2^{\phi}) - V_A N(-d_1^{\phi}) \tag{1.4}$$

$$P_{D+P} = (B_D + \phi B_P)\, e^{-r_f T} N(-d_2) - V_A N(-d_1) \tag{1.5}$$

The difference between these two put prices is equal to P_D the value of a put option on only the bonded debt.

The model is a simplified version of reality in a number of ways. First, the government has two single liabilities: B_D and B_P, which ignores the fact that in reality the government has a stream of both bonded and pension liabilities. The model assumes both of these debts are due at the same point, T, which ignores the term structure of both claims. Additionally, default can only occur at maturity, and depends solely on whether the government's asset value, V_A, is enough to cover the given liabilities. That assumption ignores the possibility of strategic default, or the inability to meet payments prior to maturity. Unfortunately data on the term-structure of pension liabilities is not readily available which makes it difficult to implement this feature in estimation. However, [27] show that pension liability duration is fairly consistent across states. Therefore, any cross-sectional conclusions from the model are likely not affected by this assumption.

Additionally, my version of the model ignores stochastic volatility, which has been proposed as a potentially important real world modification to models of this type. These assumptions are standard simplifications in a Merton model. The main mechanism I wish to explore is the effect of pension seniority. These simplifications help illuminate that feature in a straightforward way. Although these additions should not affect the qualitative predictions of my model, they could change the interpretation of my estimations which I discuss in Section 1.6.

Another shortcoming of the model is that it cannot separate loss given default and default probabilities as quantities are given under the risk-neutral measure. For the qualitative predictions I present below that is not material. The qualitative predictions serve to demonstrate which cross-sectional patterns we should expect in the data. Therefore, the directions of the relationships are not affected by any omission of risk premia. However, my estimation strategy could be biased if there are differences in risk premia across states leading to differential spreads. I will discuss that fact when interpreting the results in Section 1.6.

Finally, my modification to the seniority structure is also simplified. In reality, the priority of debts would likely not be so stark. The government would not pay out a large fraction of pension liabilities, and then bonded debt, finally making the residual pension claim. As I discussed above, in default, a negotiation would likely take place, leading to a much more nuanced payment scheme. My simple structure, however, is able to capture the end result and relative recovery rates in a parsimonious manner.

1.2.2 Model Predictions

Below, I provide three qualitative predictions of the model. These predictions describe the relationship between pension liabilities, pension liability seniority, and debt spreads. I empirically test these predictions in Section 1.4. Proofs of the predictions can be found in Appendix A.1.

PROPOSITION 1. *The debt spread is positively related to the level of pension liabilities.*

Differentiating Equation 1.3 with respect to B_P leads to:

$$\frac{\partial s_D}{\partial B_P} = -\frac{\phi}{TB_D}\left(N(d_2) - N(d_2^{\phi})\right)\left(1 - \frac{P_{D+P} - P_P}{B_D e^{-r_f T}}\right)^{-1} \geq 0 \tag{1.6}$$

PROPOSITION 2. *The debt spread is positively related to the level of pension liability seniority.*

Differentiating Equation 1.3 with respect to ϕ leads to:

$$\frac{\partial s_D}{\partial \phi} = -\frac{B_P}{TB_D}\left(N(d_2) - N(d_2^{\phi})\right)\left(1 - \frac{P_{D+P} - P_P}{B_D e^{-r_f T}}\right)^{-1} \geq 0 \tag{1.7}$$

PROPOSITION 3. *The positive relationship between debt spreads and pension liabilities is stronger for states with more senior pension liabilities.*

Differentiating Equation 1.3 with respect to ϕ and B_P leads to:

$$\frac{\partial^2 s_D}{\partial \phi \partial B_P} \geq 0 \tag{1.8}$$

The first two predictions are not novel. The ϕ parameter essentially increases the amount of senior debt, and thus has the same effect of increasing B_P directly. Thus, the junior claim (bonded debt) becomes riskier when either ϕ or B_P increases, leading to higher spreads. The third prediction is an innovation of my model. The more senior (i.e., higher ϕ) the senior claim, the more it affects junior debt. Thus, an increase in the amount of pension liabilities, B_P, will have a larger effect on the spread of bonded debt if that pension claim is more senior. In Section 1.4 I test these relationships empirically using reduced-form regressions on bond spread data for state governments.

1.3 Data Construction

In this section, I present details on state government pension and fiscal information, along with the bond spread data I use to proxy for state borrowing costs. All main conclusions hold when using CDS spreads as opposed to individual bond spreads, and more information on that data is presented in Appendix A.2. Although I control for contract features (e.g., callability, issue size, etc), in using bond data, I may be missing some feature of bonds (including liquidity) that could bias my results. Because credit default swaps are a standardized constant maturity contract, these issues are not present. Despite potential issues, I use bond spreads in my main results given the abundance of data and the ability to introduce state fixed effects into my analyses.[12]

1.3.1 Government Data

Compiled panel data on U.S. state level finances is scant. To my knowledge, the only publicly available semi-comprehensive source is the U.S. Census State Finances data. Each year the Census asks state governments by survey to fill in a number of accounting variables, which are then compiled by the Census Bureau. The Census focuses primarily on revenue and expense variables. These values capture government flows, but they do not collect balance sheet information in a comprehensive manner. Balance sheet information is more instructive for assessing longer-term state fiscal health which may be more pertinent for debt pricing. Therefore, I construct a dataset of state government finances in which I focus on balance sheet variables. These variables allow me to separate the effects of unfunded pension liabilities from other long-term debt obligations and assess their relationship with bond spreads.

Each year, state governments release a Comprehensive Annual Financial Report (CAFR). These reports reflect state government fiscal years that end June 30, and are similar to corporate 10-K filings[13]. A CAFR contains a Statement of Net Position and Statement of Activities which are equivalent to balance sheets, and income statements. I primarily use these two statements to construct the fiscal data. I focus on 2002-2016 (although my final sample will only include 2005-2016 due to bond data availability). A more detailed explanation of the data collection can be found in Appendix A.3.

With these data, I construct a number of relevant financial ratios. My data collection

12. CDS data are only available for a subset of states over a small time period which greatly lowers the power of any statistical tests.

13. The only exceptions are the following: Alabama, Michigan (Sep. 30), New York (March 31), and Texas (Aug. 31).

is similar to that done by the Mercatus Center in its 2015 and 2016 "Ranking the States by Fiscal Condition." I expand, however, on their analysis both by collecting more years of data and also more detailed line items. All variables are scaled by GDP to adjust for the size of the overall state economy. Annual GDP data are taken from the BEA. States have unlimited taxing power, and GDP proxies for the size of the tax base that a state could feasibly rely on, both in normal times and in a fiscal crisis.[14]

The three fiscal control variables I focus on in my analyses are: Expenses - Revenues (*Exp - Rev*), Current Liabilities - Current Assets (*CL-CA*), and Long-Term Liabilities - Long-Term Assets (*LTL-LTA*). Each variable is a "deficit" capturing current funding status of a different part of the government. *Exp-Rev* is the only non-stock variable I control for, and is meant to capture the relative inflow/outflow of money into the state coffers. *CL-CA* captures balance sheet obligations that the government will need to meet in the short term. Meanwhile *LTL-LTA* captures longer-term obligations. Pension liabilities are discussed in more detail below because they are not collected from the CAFR. In certain specifications and robustness checks I also use other control variables to alleviate omitted variable concerns. I describe these data as they are used in Section 1.4.

I supplement these data with pension data from the Public Plans Database (PPD) constructed by the Center for Retirement Research at Boston College. The data contains plan-level asset and liabilities data by fiscal year. I aggregate by state and year to obtain a matching panel dataset. For each state, I calculate the level of unfunded pension liabilities as pension liabilities minus pension assets. The PPD data uses reported pension liabilities which are generally discounted at the rate of asset returns (about 8%). [26] note that the use of such high discount rates drastically underestimates the value of pension liabilities. Nevertheless, I maintain the pension liabilities as reported for this analysis. In Appendix A.4, I perform my main analyses using alternative discount rate assumptions, and my results are unchanged.

14. Results are qualitatively the same when using state income in place of GDP.

In Table 1.1, I present annual summary statistics for the fiscal condition variables. Unsurprisingly, fiscal conditions worsen in 2008 - 2010 during the Great Recession, although, primarily for long-term liabilities. *(LTL-LTA)/GDP* and *(PL-PA)/GDP* went down during the financial crisis, and they have remained at these elevated levels in the years since. Thus, the recession does not appear to be a blip in state government finances but rather has had lasting effects on fiscal positions. Shorter-term liabilities in *(CL-CA)/GDP* and *(Exp-Rev)/GDP* did see a small decline during the financial crisis, but have returned to pre-recession levels. That fact is not surprising given constitutional balanced-budget requirements exist in 49 of the 50 states. These balanced-budget requirements generally apply only to state operating budgets, which allows them to skirt the requirements through capital budgets (i.e., debt) and pension funding.

Table 1.1: Fiscal Variable Time Series Summary Statistics: 2002 - 2016

	(Exp-Rev)/GDP (%)						(LTL-LTA)/GDP (%)				
Year	Mean	StDev.	Min.	Med.	Max	Year	Mean	StDev.	Min.	Med.	Max
2002	0.49	1.23	-1.35	0.20	6.15	2002	-10.23	17.20	-107.95	-7.23	1.43
2003	0.17	0.80	-1.34	0.08	4.09	2003	-9.79	15.68	-102.30	-7.53	2.03
2004	-0.42	1.64	-10.01	-0.23	1.83	2004	-9.68	15.55	-102.59	-7.77	4.12
2005	-0.65	1.27	-8.15	-0.44	0.79	2005	-9.69	14.95	-100.02	-7.76	2.53
2006	-0.81	1.51	-10.05	-0.59	0.18	2006	-9.71	14.67	-99.46	-8.06	2.34
2007	-0.88	2.35	-15.66	-0.45	0.33	2007	-10.00	15.66	-105.98	-8.50	2.47
2008	-0.19	1.55	-9.78	-0.02	1.14	2008	-9.89	15.16	-103.79	-8.23	3.09
2009	0.98	1.97	-0.64	0.56	13.11	2009	-9.31	15.12	-102.40	-7.79	4.39
2010	-0.00	1.45	-8.80	0.03	1.54	2010	-8.88	15.57	-104.25	-7.24	5.99
2011	-0.87	2.75	-16.74	-0.38	1.06	2011	-9.03	16.80	-112.79	-6.96	6.93
2012	-0.31	1.05	-6.32	-0.32	1.25	2012	-9.08	17.15	-115.16	-6.21	7.90
2013	-0.57	1.48	-9.84	-0.41	1.26	2013	-9.44	18.82	-127.08	-6.45	8.59
2014	-0.73	1.76	-10.49	-0.39	0.75	2014	-11.01	20.61	-140.90	-6.85	9.15
2015	-0.26	0.87	-1.18	-0.39	4.82	2015	-7.75	20.65	-133.70	-5.21	20.56
2016	-0.19	2.07	-9.10	-0.32	10.16	2016	-7.37	20.91	-133.76	-4.76	22.71

	(CL-CA)/GDP (%)						(PL-PA)/GDP (%)				
Year	Mean	StDev.	Min.	Med.	Max	Year	Mean	StDev.	Min.	Med.	Max
2002	-5.43	15.54	-96.91	-2.52	-0.38	2002	2.08	3.10	-2.80	1.34	12.01
2003	-4.71	14.30	-92.44	-2.08	-0.23	2003	3.01	3.31	-2.25	2.27	12.95
2004	-4.65	14.21	-92.91	-2.08	-0.36	2004	3.28	3.40	-1.93	2.75	12.22
2005	-4.57	13.49	-89.41	-2.03	-0.84	2005	3.52	3.10	-1.50	3.44	10.59
2006	-4.80	13.37	-89.83	-2.25	-0.82	2006	3.50	3.08	-1.42	3.15	10.55
2007	-5.15	14.43	-96.87	-2.43	-0.90	2007	3.26	3.04	-3.14	3.21	10.34
2008	-4.95	13.92	-95.32	-2.61	2.03	2008	3.78	3.21	-3.57	3.53	9.10
2009	-4.47	13.61	-92.87	-2.06	-0.10	2009	5.55	3.61	-1.45	5.45	13.34
2010	-4.37	13.90	-94.82	-1.86	0.14	2010	5.92	3.91	-1.21	5.41	14.72
2011	-4.69	15.26	-104.13	-2.07	-0.12	2011	5.91	3.87	-1.17	5.48	13.49
2012	-4.83	15.63	-106.75	-2.16	-0.28	2012	6.41	4.05	-1.21	5.85	14.49
2013	-5.34	17.32	-118.42	-2.50	-0.26	2013	6.39	4.12	-0.49	5.85	15.43
2014	-6.80	19.37	-131.11	-2.46	-0.24	2014	5.92	4.04	0.00	5.20	15.29
2015	-5.62	18.80	-130.97	-2.38	-0.21	2015	6.08	3.96	0.00	5.60	15.66
2016	-5.48	18.44	-127.19	-2.24	-0.06	2016	6.65	4.35	0.00	5.56	16.31

Table 1.1 presents time-series summary statistics of annual observations for the fiscal variables used in the paper. *Rev* represents total revenue, *Exp* is total expenses. *CA* and *CL* are current assets and liabilities, respectively. *LTA* is long-term assets, and *LTL* is long-term liabilities. *PA* is pension assets and *PL* is pension liabilities. All non-pension data are taken from state comprehensive annual financial reports. Pension information is aggregated at a state level using the Boston College Center for Retirement Research Public Plans Database. All variables are scaled by annual state GDP. Ratios are in percentages.

In Table 1.2, I present pension funding summary statistics by state. Large cross-sectional variation exists in the size and funding of public pensions. California has the largest pension liability at $450 billion, and Vermont has the smallest with only $3 billion. Across the board, pension liabilities increased from 2005-2015. The largest increase was again in California, with an increase of over $300 billion. Almost all states have seen increases in their unfunded liabilities as well. The pension problem in the U.S. has not been getting better, despite more awareness of potential issues. The table also shows substantial variation in the levels and changes in liabilities, both of which may have different effects on state bond yields. I also present a visual display of these statistics in Figure 1.2.

Figure 1.2: Pension Underfunding: 2014

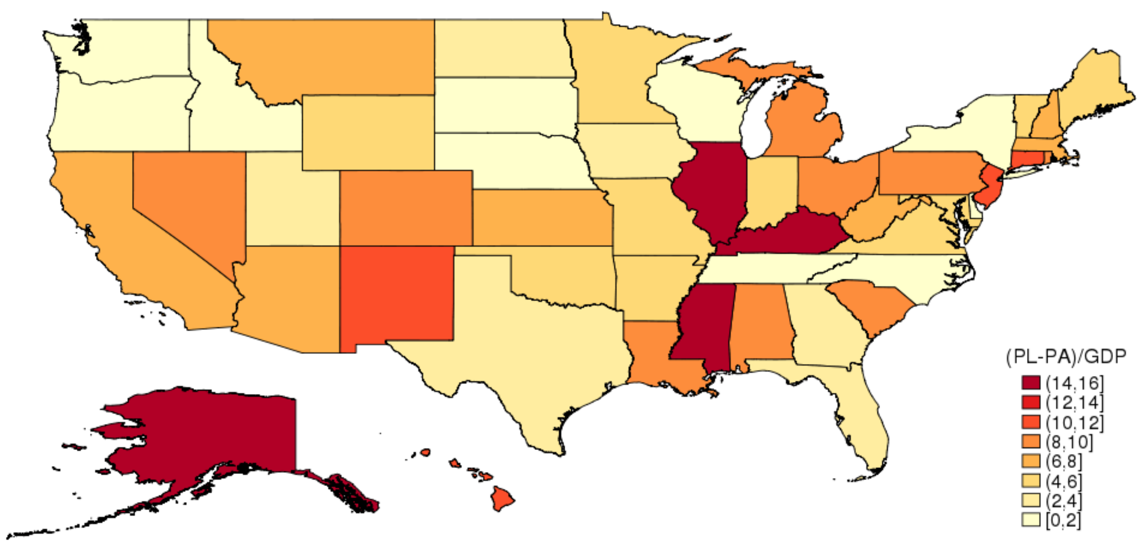

Figure 1.2 presents the pension funding ratio, $\frac{PL-PA}{GDP}$, by state for 2014. PL is pension liabilities, and PA is pension assets.

Table 1.2: Pension Funding By State: 2005-2016

State	Mean PL (bln.)	Δ PL 2005-2015	Mean PL-PA (bln.)	Δ PL-PA	Mean $\frac{PL-PA}{GDP}$
AK	14.95	8.97	5.36	1.91	10.75
AL	38.57	13.91	9.44	9.76	5.29
AR	21.17	11.14	4.37	2.75	4.10
AZ	43.52	25.05	9.60	12.72	6.18
CA	449.64	302.96	92.11	140.55	4.40
CO	61.56	20.02	19.72	13.56	7.68
CT	43.86	23.46	19.31	13.67	8.27
DE	6.92	3.48	0.21	0.85	0.29
FL	129.64	61.62	6.60	29.97	0.70
GA	76.56	38.57	10.06	20.35	2.19
HI	17.76	10.25	6.39	4.70	9.24
IA	27.74	14.30	4.30	3.46	2.91
ID	11.52	6.73	1.30	1.04	2.38
IL	159.32	111.33	72.21	76.76	10.63
IN	32.58	13.78	12.10	6.55	4.30
KS	19.19	10.23	6.44	3.80	5.02
KY	44.41	24.42	17.05	22.82	9.84
LA	42.85	20.99	15.24	8.05	7.07
MA	57.39	32.05	18.13	19.28	4.38
MD	47.96	25.36	12.35	14.41	3.84
ME	13.32	3.65	2.92	-0.27	5.84
MI	78.13	30.12	20.30	22.94	4.93
MN	56.13	23.35	9.90	9.87	3.46
MO	53.45	23.25	10.00	4.43	3.92
MS	30.18	16.64	10.13	9.43	10.55
MT	11.37	NaN	3.38	NaN	7.49
NC	73.19	34.78	0.54	9.02	0.03
ND	6.08	NaN	2.24	NaN	3.76
NE	8.11	4.54	1.19	0.39	1.27
NH	8.40	6.31	3.22	2.64	4.92
NJ	118.14	42.20	34.26	38.88	6.69
NM	27.98	15.31	7.09	7.21	8.18
NV	32.72	22.46	8.61	6.63	6.86
NY	230.56	106.80	4.79	21.34	0.26
OH	189.65	69.25	47.30	23.01	9.10
OK	27.56	8.52	9.83	-2.08	6.73
OR	55.02	26.06	4.29	10.25	2.09
PA	110.20	51.86	26.29	44.76	4.11
RI	11.81	1.71	4.57	0.37	9.36
SC	39.94	16.89	12.43	9.66	7.27
SD	7.36	4.78	0.20	-0.19	0.54
TN	34.80	16.46	1.92	1.47	0.73
TX	193.16	105.48	28.26	30.58	2.13
UT	20.70	12.56	2.84	2.73	2.36
VA	64.75	35.08	14.91	13.37	3.45
VT	3.63	2.35	0.85	1.55	3.05
WA	30.68	38.75	-2.94	9.05	-1.02
WI	77.93	22.55	0.30	-0.34	0.14
WV	13.34	6.03	5.26	-1.31	8.70
WY	6.62	3.62	1.02	1.65	2.74

Table 1.2 presents summary statistics on pension funding for states over the sample. All differences are calculated in levels from 2005-2015. Means are calculated over the full sample from 2002-2016. Dollars are in billions. *PL* represents the face value of pension liabilities, and *PA* is pension assets. Pension information is aggregated at a state level using the Boston College Center for Retirement Research Public Plans Database.

1.3.2 Municipal Bond Data

For bond yield data, I rely on two databases: the Mergent Municipal Bond Securities Database and the Municipal Securities Rulemaking Board's (MSRB) Electronic Municipal Market Access Database (EMMA). Mergent provides issue-level information such as CUSIP, offering date, maturity date, offering amount, bond type, and other characteristics such as option flags. EMMA is a transaction database, which tracks trades of municipal bonds and contains information on trade date, traded yield, and amount. I link the two datasets by CUSIP to obtain both original issue characteristics and updated pricing (yield) information. I filter for bonds issued by state governments only.

For each month, I take the last observed trade for each bond as the observation for that month[15]. If a bond does not have a trade in a given month, it has no observation in the data. I then merge these yields and characteristics to my fiscal data based on the fiscal year ends. Each trade yield is then adjusted to arrive at a pre-tax yield. Municipal bonds are generally tax-exempt at the federal, state, and local levels. Therefore, the yield of two bonds with equal credit worthiness could vary due to difference in taxes across states. In my analysis, I want to focus on credit risk, so I adjust for these cross-sectional differences by adjusting for the top marginal income tax rate (combination of state and federal) in each state.[16] The adjustment is:

$$y_{i,s,t}^{Pre-Tax} = \frac{y_{i,s,t}}{1 - \tau_{s,t}} \tag{1.9}$$

For each bond, I calculate the difference between the pre-tax yield and a maturity-matched Treasury to obtain the bond spread. To obtain the maturity matched Treasury, I interpolate between points on the Treasury yield curve to correspond to the current time-to-maturity (TTM) of an issue.[17] I use these spreads in my analyses. I control for a number of

15. Results are not changed if I take the average yield for each bond in a given month

16. This is the same tax-rate methodology used in [32], and the adjustment is based on the theoretical work of [21].

17. Results are insensitive to the use of a linear interpolation or a cubic spline. Reported results use the linear interpolation.

issue characteristics for each observed spread, including TTM, bond-type (e.g. revenue vs. GO), issue amount, and flags for callability, putability, and whether the bond is insured. For robustness in some analyses, I use only GO bonds, which are about 75% of the full sample. General obligation bonds are backed by the "full faith and credit" of the government and likely represent the purest measure of state's default risk/borrowing costs.

Summary statistics by state are contained in Table 1.3. Large cross-sectional variation exists among states. California is the most prolific issuer with 568 bonds in the sample with an average offering of over $1 billion. Meanwhile, Idaho only issued 11 bonds for an average offering of $427 million. The average maturity across states is relatively consistent, being between five and ten years. Finally, large variation exists in spreads across states. Illinois had average spreads of over 224 basis points, and Hawaii had an average spread of 67 basis points. Unsurprisingly the patterns are very similar to the patterns in the CDS data. One might be concerned that my regression analyses overweight heavy issuers such as California. However, my CDS analysis alleviates this concern because it includes only one spread per state per year, and results are qualitatively similar.

Next, in Table 1.4, I show aggregate summary statistics for my entire sample. Panel A shows the summary statistics for the full sample, and Panel B presents summary statistics for just the general obligation bonds, which are about 75% of my sample. The table shows that there is little difference between the two samples in the statistics I display: spread, TTM, trade size, and offering amount. The average spread is 164 basis points for the full sample with a slightly lower median of 150 basis points. In fact, negative bond spreads are not shocking given that many issuances are insured making them even safer than Treasuries. The average bond has 7.8 years until maturity, and an offering amount of $30 million. Meanwhile, the average trade size is $570,000. General obligation offerings appear slightly larger and also have larger trade sizes.

Table 1.3: Bond Summary Statistics by State: 2005-2016

State	Avg. Offer Amt. (Mln.)	N Bonds	Go Pct.	$\hat{s}$	med(s)	$\sigma(s)$	Avg. Monthly Trades	$\hat{TTM}$
AK	155.00	145.00	1.00	78.76	61.72	57.13	4.18	7.47
AL	112.00	43.00	1.00	75.28	63.40	45.48	3.46	9.53
AR	63.80	495.00	0.89	101.97	93.95	57.18	2.58	8.06
AZ	218.00	199.00	0.00	117.37	112.72	69.92	3.91	5.61
CA	1520.00	568.00	0.98	140.70	128.29	144.74	18.01	10.08
CT	346.00	833.00	1.00	88.64	92.25	67.51	5.33	8.01
DE	210.00	185.00	1.00	93.13	50.08	251.75	3.59	8.33
FL	207.00	424.00	0.28	96.73	92.19	126.68	4.79	9.14
GA	293.00	803.00	1.00	84.42	65.04	70.47	4.67	7.02
HI	328.00	323.00	1.00	66.87	58.63	53.99	3.28	8.96
IA	427.00	13.00	0.00	224.58	354.87	252.34	8.64	22.06
ID	461.00	11.00	0.18	41.75	34.06	37.73	2.33	0.50
IL	783.00	648.00	0.97	224.54	228.86	89.04	9.40	9.24
IN	76.00	768.00	0.00	105.96	104.14	155.88	3.68	8.54
LA	272.00	470.00	0.97	89.05	85.73	74.69	4.40	7.02
MA	368.00	717.00	0.03	64.82	66.43	68.86	7.65	8.18
MD	300.00	285.00	1.00	53.59	45.35	32.74	6.28	7.05
ME	55.00	277.00	0.94	112.01	84.72	81.08	2.56	3.21
MI	189.00	72.00	0.85	86.06	79.00	56.50	3.47	7.06
MN	296.00	793.00	0.96	67.97	61.81	59.50	4.97	7.55
MS	136.00	191.00	1.00	101.50	103.19	44.90	3.51	8.52
MT	9.74	321.00	0.90	84.97	75.35	82.42	1.59	5.86
NC	333.00	485.00	0.97	63.26	63.87	90.33	6.10	5.89
NH	71.40	475.00	1.00	96.50	83.14	100.58	3.37	6.51
NJ	359.00	328.00	0.96	96.42	91.85	70.76	7.89	5.62
NM	129.00	84.00	0.85	65.96	56.24	43.80	3.08	2.99
NV	49.60	724.00	0.01	96.12	90.73	57.58	2.80	7.54
NY	217.00	268.00	1.00	94.36	90.65	55.75	5.61	8.91
OH	114.00	296.00	0.84	66.07	64.02	32.79	2.81	7.99
OR	58.00	459.00	0.94	73.92	69.98	51.81	2.16	10.14
PA	501.00	550.00	1.00	91.76	83.55	61.23	7.63	7.73
RI	75.70	395.00	0.91	111.26	96.54	80.61	2.83	6.42
SC	28.40	375.00	0.33	56.34	44.88	41.31	2.21	7.04
TN	159.00	449.00	0.92	79.19	67.05	60.54	3.85	7.51
TX	387.00	771.00	0.91	72.50	72.57	75.76	2.94	10.02
UT	337.00	202.00	0.96	68.58	55.76	51.73	6.92	3.93
VA	131.00	557.00	0.97	75.79	68.72	48.31	3.40	7.75
VT	35.80	601.00	0.98	85.58	72.84	70.69	2.31	6.18
WA	309.00	830.00	0.53	85.40	76.30	53.31	7.35	9.26
WI	274.00	119.00	1.00	74.40	73.21	32.30	2.56	8.98
WV	99.80	184.00	1.00	106.47	97.39	150.09	3.34	5.60
WY	802.00	2.00	0.00	217.68	217.68	NaN	3.57	16.92

Table 1.3 presents summary statistics from state-level municipal bond data. Data are a combination of issue information from Mergent, and trade information from EMMA. s represents the pre-tax yield of the bond minus a maturity matched treasury (i.e. spread), and is measured in basis points. GO Pct. is the fraction of GO bonds. TTM is measured in years. Avg. Monthly Trades is the average monthly trades per bond.

Table 1.4: Bond Sample Summary Statistics: 2005-2016

Panel A: Full Sample

	Mean	StDev	p_1	p_{10}	p_{25}	p_{50}	p_{75}	p_{90}	p_{99}
s (bp)	164.47	333.73	-305.45	17.89	82.92	151.63	244.77	377.13	730.67
TTM	7.82	5.97	0.13	1.16	3.07	6.48	11.17	16.41	25.61
Amt. Traded (mln.)	0.57	3.12	0.01	0.01	0.01	0.03	0.10	0.50	12.04
Offering Amt (mln.)	30.80	155.85	0.28	2.00	5.43	13.04	26.95	53.09	301.00

Panel B: GO Only

	Mean	StDev	p_1	p_{10}	p_{25}	p_{50}	p_{75}	p_{90}	p_{99}
s (bp)	167.28	318.53	-305.42	15.08	81.68	152.71	250.95	393.12	733.69
TTM	7.84	5.98	0.13	1.16	3.09	6.52	11.27	16.48	25.36
Amt. Traded (mln.)	0.60	3.10	0.01	0.01	0.01	0.03	0.10	0.50	13.10
Offering Amt (mln.)	32.30	150.47	0.38	2.45	6.64	14.57	28.39	55.46	306.80

Table 1.4 presents summary statistics from state-level municipal bond data. Data are a combination of issue information from Mergent, and trade information from EMMA. s represents the yield of the bond minus a maturity-matched treasury (i.e., spread), and is measured in basis points. Amt. Traded is the size of each trade. Offering Amt. is the size of the initial maturity offering. Panel A represents the full sample. Panel B is limited to GO bonds which are about 75% of the sample. Time period covered is 2005 - 2016.

1.4 Bond Spreads and Unfunded Pension Liabilities

In this section, I study the relationship between state bond spreads and public pensions. First, I look at the reduced-form relationship between unfunded pension liabilities and state bond spreads. I then perform event-study exercises to demonstrate a causal link between the two variables. Next, I decompose the pension funding ratio to better understand what drives this relationship. Finally, I investigate how the effect of unfunded pension liabilities on debt spreads varies with the term structure.

1.4.1 Reduced-Form Results

Given that state government fiscal data corresponds to the end of the fiscal year, I match bond spreads to the date of the end of each fiscal year.[18] My main sample is a panel of 64,139 observations across 42 states from 2005-2016.[19] I perform a number of reduced-form regressions with spread levels on the left-hand side and the ratios described above on the right-hand side, along with additional control variables.

The general specification I use is the following:

$$s_{i,s,t} = \alpha_t + \alpha_s + \beta \frac{PL_{s,t} - PA_{s,t}}{GDP_{s,t}} + \gamma^{'} X_{s,t} + \nu^{'} Y_{i,s,t} + \epsilon_{i,s,t} \tag{1.10}$$

where $s_{i,s,t}$ is the spread of bond i in state s in year t. X includes the state-level ratios discussed above: *(Exp-Rev)/GDP*, *(CL-CA)/GDP*, and *(LTL-LTA)/GDP*. The state fixed effect picks up any other constant differences across states, although I present some specifications without state fixed effects to show the impact of persistent differences in pension funding within states. The time fixed effects control for annual unobserved common variation across states.[20] Standard errors are clustered at the state-year level to account for correlations in errors within the same unit as my main variables of interest.[21] $Y_{i,s,t}$ represents bond-level controls, which include level variables for TTM, issue size, and trade size. I could also use the log of these variables and results are unchanged. Meanwhile, I also have indicator variables for whether or not the bond is insured, whether it is callable or puttable, and what type of bond it is (i.e., revenue vs. GO).

An additional concern with the above specifications arises from the relationship between

18. I also run my main regressions by lagging bond data by six months under the concern that CAFRs are reported with a lag. Results are unchanged qualitatively when I make this modification.

19. Eight states do not have any bond trades in my sample.

20. [1] show there is a strong systemic component in state-level CDS spreads.

21. Column 4 includes results clustered at the state level only. One might be concerned that state-year clustering may not be appropriate given the small number of year clusters. As the table shows results are not sensitive to this specification. Results are also consistent when clustering at the CUSIP level.

fiscal variables and economic conditions. A government's finances are driven by economic conditions within a state, and my results may only be capturing the effects of good (or bad) economic times. Therefore, in some specifications, I control for economic conditions separately. Dividing each liability number by GDP does so in part, but only captures part of the economic environment. The Federal Reserve of Philadelphia constructs a monthly economic coincidence index at the state level that combines various measures of the local economy including unemployment, output, and income. I add these state indices, along with the Case-Shiller housing-price index.

I scale all non-dummy variables by their full-sample standard deviation. Coefficients can be interpreted as the marginal change in debt spread (in basis points) for a one-standard-deviation change in the right-hand-side variable. Results for my main specification are in Table 1.5. Columns 1-2 present the simple specification without economic and housing indices. Columns 2, 3, and 4 include state effects. Column 4 limits the sample to only GO bonds, which may be a truer measure of the full credit risk of a state as discussed above. The coefficient β will be a test of Prediction 1, which posits that $\beta \geq 0$.

The directional effect of each variable is consistent with economic intuition. Almost all fiscal condition ratios enter with a positive sign. The *CL-CA* coefficient is negative in columns 3 and 4 although it is not statistically significant. The positive coefficient on *PL-PA* is consistent with Prediction 1 from the model. Moreover, this fiscal variable is the only one that is statistically significant in all specifications, which provides evidence of a strong relationship between unfunded pension liabilities and state bond spreads. Although the long-term debt ratio (*LTL-LTA*) is statistically significant and similar in magnitude to pension funding in specifications 1 and 2, the coefficient is much smaller and not statistically significant after including the economic and housing indices. This finding suggests the long-term debt ratio is more tightly correlated with economic conditions. Meanwhile, the pension funding coefficient remains relatively unchanged when I include the indices, suggesting its effects are independent of economic conditions. The economic and housing indices enter with a negative sign as higher values indicate better economic conditions within a state, and therefore lower credit risk.

Table 1.5: State Bond Spreads and Pension Funding Regressions

	(1)	(2)	(3)	(4)	(5)
PL-PA	13.49***	27.42**	32.29***	32.29**	26.58***
	(3.50)	(2.29)	(3.20)	(2.54)	(2.92)
Exp-Rev	3.084	5.252	0.719	0.719	-0.593
	(0.75)	(1.36)	(0.26)	(0.21)	(-0.20)
CL-CA	3.787**	42.51**	-5.669	-5.669	-28.83
	(1.97)	(2.07)	(-0.34)	(-0.20)	(-1.36)
LTL-LTA	10.87**	23.88***	9.315	9.315	6.975
	(2.38)	(2.93)	(1.40)	(1.15)	(0.89)
Econ. Index			-9.017	-9.017	-28.64*
			(-0.73)	(-0.71)	(-1.93)
Housing Index			-58.59***	-58.59***	-66.66***
			(-6.57)	(-7.12)	(-6.99)
N	64139	64139	63407	63407	48018
R^2	0.240	0.245	0.248	0.248	0.277
Within R^2	0.128	0.117	0.122	0.122	0.135
Year FE	Yes	Yes	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes	Yes
Bond Controls	Yes	Yes	Yes	Yes	Yes
Sample	All	All	All	All	GO
Cluster	State Year	State Year	State Year	State	State Year

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 1.5 presents results from reduced-form regressions of annual state bond spreads over Treasuries on pension funding and other control variables. Each row indicates the numerator of the right hand side variable, which is then scaled by state-level GDP. The sample is based on annual data, where spreads are picked to match the end of fiscal years. *Rev* represents total revenue, *Exp* is total expenses, *CL* is current liabilities, *CA* is current assets, *LTA* is long-term assets, *LTL* is noncurrent liabilities, *PL* is pension liabilities, and *PA* is pension assets. All non-dummy variables are scaled by their sample standard deviations. Thus, a coefficient represents the marginal effect of a standard deviation in the right hand side variable on the debt spread in basis points. Within R^2 is the R^2 once controlling for fixed effects (i.e., cross-sectional R^2). R^2 is adjusted R^2. Bond controls include TTM, issue size, and indicators for bond type, insurance, callability, and putability. Econ Index is the Philadelphia Federal Reserve State Coincident Index. Housing Index is the state Case-Shiller price index.

Quantitatively, columns 2 and 3 show that a state/year with a one-standard-deviation higher unfunded pension liability ratio is associated with a 27–32 basis point higher bond spread. The magnitude of the other fiscal variables is much smaller in general. The housing index has the largest relationship with a one-standard-deviation change leading to a 67 basis point change in spreads. Housing prices likely provide a lot of information on underlying economic conditions within a state. They may also proxy for the ability to raise tax revenue which is closely related to the asset value in the model. Column 1 shows the relationship between pension funding and spreads is actually lower when not including state fixed effects. That finding implies persistent differences exist within states, which lower spreads, and are not captured by my other fiscal controls. With R^2 values around 0.25, I explain a reasonable amount of the variation in spreads with this specification. The explanatory power is similar to that in reduced-form studies of corporate credit spreads (e.g., [9]).

One question of interest is, What is the dollar magnitude of these effects? That is, how much are states actually paying in terms of extra borrowing costs due to unfunded pension liabilities? I first provide an example to illustrate how I calculate the magnitude of these effects. From my reduced-form regressions a one-standard-deviation improvement in the pension funding to GDP ratio is associated with a 26.58 bp increase in spreads (column 4). For Illinois in 2016, if the state had moved to full funding, it would have had a 79 basis points improvement in spread (3 standard deviations). In 2016, Illinois issued \$2.8 billion in GO bonds for proceeds of \$3 billion. With a 79 bp lower yield on each issue, the state would have raised an additional \$280 million (calculated by re-valuing each bond at issuance). If you extend this calculation to all states, in 2016, if states had full pension funding, they would have collectively raised an additional \$2 billion.

In many ways, this is a lower bound on the likely dollar impact. I use the lower of my reduced-form estimates. Also, this calculation only accounts for issuance proceeds. It ignores ongoing higher borrowing costs on all existing bonds due to higher interest rates. Nevertheless, it provides an instructive example of the large magnitude of these effects. These results, however, do not necessarily tell a causal story, because omitted variables could be present that are correlated with pension funding. Even after controlling for state and year fixed effects, these omitted variables could drive an increase in spreads. In Appendix A.5 I show my results are robust to including additional variables related to tax revenues and rates. In the next subsection, I use event study exercises to demonstrate a causal mechanism and also benchmark these quantitative impacts.

1.4.2 Event Studies

To understand the causal relationship between pension funding and spreads, I implement two event study analyses. In an ideal experiment, I would observe an exogenous shock to pension funding levels and could measure the instantaneous reaction of bond spreads to that shock. I use the passage of pension reform legislation and legal decisions relating to those reforms as proxies for shocks to pension funding. I examine bond spread reactions in response to the passage of, and later court overturning of, a pension reform in Illinois. Although there exist instances of pension reforms being enacted and overturned, they generally do not specifically apply at the state-level. For example, in 2019 the California State Supreme Court overturned a pension reform in San Diego. Because my paper is focused on the relationship between state bond spreads and pension funding, I focus on state-level events.[22]

On December 3, 2013, the state of Illinois passed legislation that extended retirement ages and limited the amount of salary used to calculate pension benefits. The law was estimated to reduce the state's pension liability by approximately $160 billion.[23] However, in May 8, 2015, the State Supreme Court struck down the law, deeming it unconstitutional. I treat passage of this legislation and the court decision as shocks to the pension funding ratio of Illinois. In practice, I assume passage of the legislation reduced Illinois' pension liability by $160 billion, and the Supreme Court ruling then increased the liability by the same amount.

22. Kentucky overturned a state-level pension reform law in 2019. Unfortunately there are not enough state-level bonds at this period with which to have any power to perform such an event study.

23. "Illinois supreme court overturns state's 2013 pension reform law," Reuters. May 8, 2015.

Below, I discuss the ramifications of the likely scenario where the legislation and subsequent decision were anticipated. I perform a difference-in-differences event study of the following form in which I compare spreads on Illinois bonds prior to the announcement and after to spreads in other states:

$$s_{i,t} = \alpha + \nu IL_i + \theta POST_t + \beta(POST_t \times IL_i) + \gamma X_{i,t} + \epsilon_{i,t}$$

$s_{i,t}$ represents the credit spread of bond i at time t. IL_i is an indicator for whether the bond is issued by Illinois. $POST_t$ is an indicator for whether the trade took place after the event in question. $X_{i,t}$ are issue-level controls including TTM, offering amount, along with callability, putability and bond insurance indicators. I use various window sizes around the date, t, of the event. The coefficient of interest is β, which measures the difference in pre- and post-event bond spread averages in Illinois as compared to all other states. In other words, β measures the impact of the pension legislation and court decision in Illinois, using all other states as a control group. Results from the passage of the legislation can be found in Table 1.6. Results from the overturn of the law are in Table 1.7.

Table 1.6: Pension Event Study: Illinois Reform Passage

	(1)	(2)	(3)
Post x Illinois	-22.38***	-20.51***	-12.46***
	(-13.83)	(-21.71)	(-6.77)
N	121853	63315	21579
R^2	0.173	0.185	0.158
Cluster	State	State	State
Controls	Yes	Yes	Yes
Window	30 days	15 days	5 days

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 1.6 presents results from an event study analysis on the passage of pension reform legislation in Illinois on December 3, 2013. The event study difference-in-difference specification is: $s_{i,t} = \alpha + \nu IL_i + \theta POST_t + \beta(POST_t \times IL_i) + \gamma X_{i,t} + \epsilon_{i,t}$. Window indicates how many days of data are used on each side of the event. Bond controls include TTM, issue size, and indicators for bond type, insurance, callability, and putability. β coefficients are presented in the table. Coefficient is in basis points.

Table 1.7: Pension Event Study: Illinois Reform Overturn

	(1)	(2)	(3)
Post x Illinois	69.88***	62.80***	46.88***
	(14.31)	(12.66)	(9.40)
N	119978	61529	22863
R^2	0.192	0.200	0.234
Cluster	State	State	State
Controls	Yes	Yes	Yes
Window	30 days	15 days	5 days

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 1.7 presents results from an event study analysis on the court overturn of pension reform legislation in Illinois on May 8, 2015. The event study difference-in-difference specification is: $s_{i,t} = \alpha + \nu IL_i + \theta POST_t + \beta(POST_t \times IL_i) + \gamma X_{i,t} + \epsilon_{i,t}$. Window indicates how many days of data are used on each side of the event. Bond controls include TTM, issue size, and indicators for bond type, insurance, callability, and putability. β coefficients are presented in the table. Coefficient is in basis points.

The results show that spreads decreased, on average, by 12.46 basis points in Illinois as compared to other states following the passage. I use this estimate to perform a back-of-the-envelope calculation, and compare the estimate to my reduced form coefficient in Table 1.5. A decrease in liabilities of \$160 billion (in present value terms) would decrease Illinois' pension funding to GDP ratio by 0.63 standard deviations. Thus, a one standard deviation change in the funding ratio would lead to a 20 basis point decrease in spread ($12.46bp/0.63sd = 20bp/sd$). Therefore, the implied coefficient is similar in magnitude to the 27 bp estimate in my main regression. The magnitude, along with the statistical significance of the coefficient, suggests the relationship between pension funding and debt spreads is in fact causal.

The impact of the overturning of the ruling is even larger. Table 1.7 shows a 47 basis point increase in spreads following the court decision. The coefficient corresponds to a 74 basis point increase in spreads for a one-standard-deviation change in unfunded pension liabilities ($46.88bp/0.63sd = 74bp/sd$). The event study implied coefficient is higher than that in the cross-sectional regressions, suggesting my reduced-form estimates may underestimate the causal effect. Moreover, if either of these events were partially anticipated prior to the dates I use in the regression, this will bias my coefficients downward. This downward bias is likely the case because the court decision was unanimous. Therefore, I am comfortable in stating that the true causal impact of pension shocks is likely higher in nature.

These event study exercises show statistically significant reactions of bond spreads around pension reform legislation and court decisions. If these "shocks" were partially anticipated, my estimates actually underestimate the impact of pension funding on spreads. Thus, I provide strong evidence of a causal relationship between pension funding and state bond spreads.[24] Moreover, the quantification of the results suggests my reduced-form estimates in Table 1.5 are a reasonable quantification of the effect of unfunded pension liabilities on state bond spreads and therefore state borrowing costs. It is worth nothing the asymmetry in reaction size across the two events. The initial reaction was likely due to markets reacting to the individual reform itself. The overturning, however, was likely a signal about the likelihood of future reform as well. Therefore, it may not be surprising that this event led to a stronger movement in spreads.

I perform one additional analysis on the causal link between pension funding and state bond spreads. [32] shows that municipal bond spreads are driven by default risk as opposed to liquidity risk. He uses a quasi-natural experiment with pre-refunding bonds similar to that in [25] to make this claim. I perform a similar analysis below.

A common practice for municipalities is "refunding" as a way of rolling over debt. Municipalities issue new bonds and hold the proceeds in escrow to refund an old issuance upon reaching its call date. A pre-refunded bond is a bond for which the state has already received the proceeds to retire the bond. As such, these bonds should no longer have any default risk. Therefore, changes in unfunded pension liabilities should not have an effect on these bonds. I confirm this fact by running additional regressions where I interact pension funding with an indicator for whether a bond has been pre-refunded. Results can be found in Table 1.8.

24. Parallel trend graphs in fact suggest these may be underestimates.

Columns 2 and 4 show the effect of pension funding on state bond spreads is driven primarily by non pre-refunded bonds. That finding suggests the pension funding channel is one of default risk. The difference between the two coefficients in column 4 is not statistically different from zero, which suggests pension funding has no effect on pre-refunded bonds, which should have zero default risk. In fact, including the pre-refunded bonds in my main specification may be biasing my results downward because the coefficients are now higher after controlling for it. Moreover, these results further the idea that this relationship is causal because they imply a default risk mechanism. In the following two subsections, I perform two additional analyses that further explore the relationship between pension funding and state bond spreads.

1.4.3 Pension Funding Decomposition

So far I have been agnostic as to what drives changes in the pension funding ratio. Pension funding might be driven primarily by either changes in liabilities or assets. These facts could have different implications for policymakers if they are trying to reduce borrowing costs by improving pension underfunding. In this section, I decompose the pension funding ratio to shed some light on this distinction.

Table 1.8: Pre-Refund Regressions

	(1)	(2)	(3)	(4)
PL-PA	32.29***	35.05***	26.58***	31.40***
	(3.20)	(3.33)	(2.92)	(3.32)
Exp-Rev	0.719	0.558	-0.593	-0.808
	(0.26)	(0.20)	(-0.20)	(-0.27)
CL-CA	-5.669	-4.839	-28.83	-28.05
	(-0.34)	(-0.28)	(-1.36)	(-1.32)
LTL-LTA	9.315	8.653	6.975	5.662
	(1.40)	(1.32)	(0.89)	(0.74)
Pre-Refund * PL-PA		-9.044		-15.36**
		(-1.58)		(-2.04)
N	63407	63407	48018	48018
R^2	0.248	0.248	0.277	0.278
Within R^2	0.122	0.122	0.135	0.135
Year FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Bond Controls	Yes	Yes	Yes	Yes
Sample	All	All	GO	GO
Cluster	State Year	State Year	State Year	State Year

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 1.8 presents results from reduced-form regressions of annual state bond spreads over Treasuries on pension funding and other control variables. Each row indicates the numerator of the right hand side variable, which is then scaled by state-level GDP. The sample is based on annual data, where spreads are picked to match the end of fiscal years. *Rev* represents total revenue, *Exp* is total expenses, *CL* is current liabilities, *CA* is current assets, *LTA* is long-term assets, *LTL* is noncurrent liabilities, *PL* is pension liabilities, and *PA* is pension assets. Pre-Refund is an indicator for whether a bond has been pre-refunded. All non-dummy variables are scaled by their sample standard deviations. Thus, a coefficient represents the marginal effect of a standard deviation in the right hand side variable on the debt spread in basis points. Within R^2 is the R^2 once controlling for fixed effects (i.e. cross-sectional R^2). R^2 is adjusted R^2. Bond controls include TTM, issue size, and indicators for bond type, insurance, callability, and putability. Econ Index is the Philadelphia Federal Reserve State Coincident Index. Housing Index is the state Case-Shiller price index. Both indices are also included on the right hand side of the regression.

In Table 1.9, I present summary statistics for each component of the pension funding ratio. Panel A contains summary information on PL, PA, and GDP in levels, and Panel B presents summary information on annual changes in the variables. Panel B is particularly instructive for understanding what drives the variation in the pension funding ratio. On average, liabilities change more than assets year to year (mean of 5.36% vs. 4.09%), and the standard deviation of the level in liabilities is larger than that of assets over time. These two facts imply pension liabilities are a more dominant component for variation in the numerator of the pension funding ratio. Meanwhile, the average change in the numerator (*PL-PA*) is larger than that of GDP (mean of 8.74% vs. 3.47%). The actual pension funding level should dominate changes in GDP when considering differences in the entire funding ratio. Therefore, the effects I find in Table 1.5 are driven by pension funding itself and not movements in GDP.

Table 1.9: Pension Funding Ratio Decomposition: 2005-2016

Panel A: Levels ($ bln.)

	Mean	StDev	p_1	p_{10}	p_{25}	p_{50}	p_{75}	p_{90}	p_{99}
PA	50.23	69.60	2.85	6.68	11.45	28.05	56.75	114.50	406.00
PL	64.88	87.78	3.60	8.19	16.05	39.50	70.30	151.00	520.50
PL-PA	14.65	23.68	-6.54	0.38	2.59	8.28	17.00	33.60	124.50
GDP	309.02	380.65	25.97	47.53	73.73	195.50	386.31	644.68	2010.11

Panel B: Annual Changes (%)

	Mean	StDev	p_1	p_{10}	p_{25}	p_{50}	p_{75}	p_{90}	p_{99}
Δ PA	4.09	5.44	-13.16	-1.56	1.02	4.18	7.11	10.13	18.67
Δ PL	5.36	3.38	-4.67	2.58	3.78	5.05	6.85	8.81	16.48
Δ (PL-PA)	8.74	92.67	-237.08	-16.01	-1.86	7.32	18.07	47.91	251.53
Δ GDP	3.47	3.60	-6.28	-0.34	2.09	3.52	5.02	6.90	15.15
$\Delta\ \frac{(PL-PA)}{GDP}$	5.36	88.34	-230.95	-20.77	-5.32	3.66	14.68	44.44	234.14

Table 1.9 presents summary statistics for the individual components of the pension funding ratio. *PL* is pension liabilities, and *PA* is pension assets. Panel A presents summary statistics in levels. Panel B presents summary statistics for annual changes.

For reference, I also present summary statistics on the portfolios of pension assets from the plans in my sample in Table 1.10. Panel A displays the full-sample summary, and Panels B-D display summary statistics for a subset of years. The average state has over 50% of their assets in equities, with an additional 25% in fixed income for the full sample. The full-sample variations in holdings and returns are fairly moderate. Panels B-D show little cross-sectional variation in holdings or returns within years. Although, substantial time-series variation exists in returns. Using year fixed effects in my regressions should control for these state-invariant portfolio properties and ensure common time-series variation is not driving the pension coefficient. Additionally, both equity holdings and fixed-income holdings decrease over time as plans move more money into alternative investments. Both sets of summary statistics suggest differences in pension assets are not the dominant factor in the relationship between pension funding and bond spreads. I test that implication more rigorously in my decomposition regressions below.

Next, I decompose the pension funding ratio into its components and perform my main regression analyses with the individual variables on the right-hand side. Results from the regressions are in Table 1.11. All other control variables from the main regressions (including housing and economic indices) are still included, although I omit their coefficients for simplicity of presentation. Column 1 represents my main specification from Table 1.5. Column 2 includes the numerator (*PL-PA* (Raw)) and denominator (GDP) separately on the right-hand side. Finally, Column 4 includes *PL*, *PA*, and GDP separately.

Table 1.10: Pension Asset Decomposition: 2007-2016

Panel A: Full Sample

	Mean	StDev	p_1	p_{10}	p_{25}	p_{50}	p_{75}	p_{90}	p_{99}
Eq. Pct.	52.69	9.66	24.22	39.19	47.96	54.25	59.18	63.09	71.26
FI Pct.	26.70	6.79	13.54	18.55	21.82	25.50	30.79	36.26	46.30
Eq. Ret.	6.88	19.41	-39.86	-26.92	-6.41	14.68	21.67	30.29	34.25
FI Ret.	6.46	5.02	-7.55	0.65	4.04	6.44	8.34	12.88	18.52

Panel B: 2007

	Mean	StDev	p_1	p_{10}	p_{25}	p_{50}	p_{75}	p_{90}	p_{99}
Eq. Pct.	59.38	7.00	39.10	50.04	55.51	60.00	64.01	68.13	74.80
FI Pct.	27.50	7.49	15.20	20.06	22.68	26.00	30.86	36.68	50.00
Eq. Ret.	20.50	5.02	5.59	13.09	19.61	22.18	23.19	25.05	27.08
FI Ret.	7.06	2.09	4.90	5.74	6.22	6.63	7.00	8.08	15.58

Panel C: 2011

	Mean	StDev	p_1	p_{10}	p_{25}	p_{50}	p_{75}	p_{90}	p_{99}
Eq. Pct.	52.21	9.37	28.02	38.41	47.37	54.08	58.23	62.67	71.36
FI Pct.	25.62	6.22	16.47	18.33	20.67	24.95	29.15	35.15	43.04
Eq. Ret.	24.77	12.69	-9.40	-2.80	22.44	31.27	32.01	32.71	33.87
FI Ret.	6.85	1.73	3.07	4.94	5.52	6.55	7.83	9.82	10.39

Panel D: 2015

	Mean	StDev	p_1	p_{10}	p_{25}	p_{50}	p_{75}	p_{90}	p_{99}
Eq. Pct.	51.44	12.74	22.40	33.31	45.61	52.30	59.58	65.98	67.00
FI Pct.	24.28	7.33	12.99	14.80	18.45	22.80	31.33	33.47	34.70
Eq. Ret.	2.95	0.74	1.92	2.16	2.41	2.69	3.65	4.00	4.35
FI Ret.	1.41	1.14	-0.07	0.16	0.60	1.26	1.99	3.06	3.99

Table 1.10 presents summary statistics on pension asset holdings and returns within my sample. Plan-level variables are aggregated at the state level. Returns are value-weighted.

Table 1.11: Pension Funding Decomposition Regressions

	(1)	(2)	(3)
PL-PA	32.29***		
	(3.20)		
PL-PA (Raw)		121.2***	
		(8.06)	
GDP		-470.4***	-516.3***
		(-8.68)	(-7.28)
PL			454.2***
			(8.06)
PA			-304.2***
			(-5.11)
N	63407	63407	63407
R^2	0.248	0.250	0.250
Within R^2	0.122	0.124	0.124
Year FE	Yes	Yes	Yes
State FE	Yes	Yes	Yes
Bond Controls	Yes	Yes	Yes
Sample	All	All	All
Cluster	State Year	State Year	State Year

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 1.11 presents results from reduced-form regressions of annual state bond spreads over Treasuries on pension funding variables and other control variables. Each row indicates the numerator of the right hand side variable, which is then scaled by state-level GDP. *PL* is pension liabilities, and *PA* is pension assets. *PL-PA* (Raw) is the level of unfunded liabilities. *PL-PA* is the level of unfunded liabilities scaled by GDP. All non-dummy variables are scaled by their sample standard deviations. Thus, a coefficient represents the marginal effect of a standard deviation in the right hand side variable on the debt spread in basis points. Within R^2 is the R^2 once controlling for fixed effects (i.e., cross-sectional R^2). R^2 is adjusted R^2. Bond controls include TTM, issue size, and indicators for bond type, insurance, callability, and putability. Econ Index is the Philadelphia Federal Reserve State Coincident Index. Housing Index is the state Case-Shiller price index. Both indices are included in each regression. Regressions also include the fiscal variables: *Exp-Rev*, *CL-CA*, and *LTL-LTA*.

The results show each component of the pension funding ratio has a statistically significant relationship with bond spreads. Column 2 shows that effects from GDP may dominate the effects of the pension funding ratio. However, the pension funding level still has a large positive statistically significant relationship with spreads. Meanwhile, column 3 shows that pension liabilities have a positive relationship with spreads, whereas assets have a negative relationship, both being statistically significant. The larger liability coefficient implies this component of pension funding has a stronger relationship with spreads. However, the effects of all three components are similar in magnitude. These regression results show my results in Table 1.5 are not being driven by a specific component of the pension funding ratio.

The analysis in this subsection alleviates concerns that my main results are solely being driven by a specific component of the pension funding ratio. When decomposed, each component has a statistically significant relationship with spreads. The effect of liabilities, however, is larger in magnitude than that of assets. From a policy standpoint, the larger effect of liabilities implies that decreasing pension liabilities may have the largest effect on reducing borrowing costs for state governments.

1.4.4 Term Structure Analysis

In this subsection, I explore how the relationship between unfunded pension liabilities and state bond spreads varies with the term structure of debt. Many pension liabilities are not due for a number of years, and states are not likely to face a default crisis due to pension liabilities in the near future. Therefore, bonds with longer maturities may be more sensitive to changes in pension funding because they are more likely to affect repayment. To test that hypothesis, I split the main sample into buckets based on the maturity of the bonds, and then perform my main specification for each bucket separately. Results can be found in Table 1.12.

From left to right, I move from shorter to longer-term maturities. Columns 1 and 2 represent maturities of fewer than one year and one to three years, respectively. For neither of these subsamples is the coefficient on pension funding statistically significant. However, in columns 4-6 we see a statistically significant relationship between unfunded pension liabilities and bond spreads. Moreover, this effect is increasing with the term-structure. Although the effect of pension funding on three to five year bonds is 25 basis points, the effect increases to 53 basis points for bonds with more than 20 years to maturity. We see a similar pattern for the *LTL-LTA* ratio.

These results confirm the hypothesis above. Pension concerns are larger further out in the term structure, which implies short-term borrowing costs may not be affected by unfunded pension liabilities. The effect on longer-term maturities is almost the double the magnitude of my baseline estimate in Table 1.5. The five- to ten- and ten- to twenty-year buckets have the largest amount of bond observations (over half the sample), which implies the larger effects further out in the term structure are relevant for a significant portion of the full sample.

These results also have strong implications for the term structure of pension induced default events. The larger the effect of pension funding on borrowing costs, the higher effect of funding on default probabilities. Columns 1 and 2 imply a small likelihood of pension induced solvency issues in the next three years. Meanwhile, the 58 basis point estimate for the 10- to 20-year bucket in column 5 implies this window is the one in which pension liabilities would most likely begin to cause default concerns for state governments. That finding may help provide policymakers with a timeline for fixing pension issues to avoid serious fiscal crises.

The results in this section demonstrate a strong relationship between unfunded pension liabilities and state bond spreads, consistent with Prediction 1 of my model. In my reduced-form results, a one-standard-deviation change in the unfunded pension liability to GDP ratio is associated with a 27–32 basis point increase in spreads. Event study exercises provide evidence that this relationship is causal and that the actual magnitude may be larger. The effect led to over $2 billion in lost bond issuance proceeds by states in 2016. I also show this relationship is not driven solely by a specific component of the pension funding ratio, although, the level of pension liabilities appear to have a slightly larger effect on spreads than do assets. Finally, I show the effect of unfunded pension liabilities on spreads is larger for bonds with longer-term maturities. In the next section, I turn to exploring in more depth how the political economy of each state affects this relationship.

Table 1.12: Term Structure Regressions

	(1)	(2)	(3)	(4)	(5)	(6)
PL-PA	23.38	5.307	25.12*	26.60***	58.81**	53.34*
	(1.62)	(0.53)	(1.88)	(2.76)	(2.28)	(1.65)
Exp-Rev	-3.228	4.233	-2.641	4.524	7.235	32.52
	(-0.77)	(1.14)	(-0.86)	(1.19)	(1.47)	(0.69)
CL-CA	-33.43*	7.914	6.773	20.19	14.84	-849.6
	(-1.68)	(0.37)	(0.33)	(0.86)	(0.58)	(-1.39)
LTL-LTA	1.800	17.34**	1.226	17.02**	16.13	97.28***
	(0.19)	(2.25)	(0.15)	(2.16)	(1.30)	(4.03)
N	4801	10406	9610	19088	16596	2894
R^2	0.402	0.321	0.182	0.183	0.192	0.222
Within R^2	0.0461	0.0164	0.0253	0.0465	0.0834	0.151
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Sample	All	All	All	All	All	All
Cluster	State Year	State Year	State Year	State Year	State Year	State Year
Maturity	[0,1)	[1,3)	[3,5)	[5,10)	[10,20)	20+

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 1.12 presents results from reduced-form regressions of annual state bond spreads over Treasuries on pension funding and other control variables. Each row indicates the numerator of the right hand side variable, which is then scaled by state-level GDP. The sample is based on annual data, where spreads are picked to match the end of fiscal years. *Rev* represents total revenue, *Exp* is total expenses, *CL* is current liabilities, *CA* is current assets, *LTA* is long-term assets, *LTL* is noncurrent liabilities, *PL* is pension liabilities, and *PA* is pension assets. All non-dummy variables are scaled by their sample standard deviations. Thus, a coefficient represents the marginal effect of a standard deviation in the right hand side variable on the debt spread in basis points. Within R^2 is the R^2 once controlling for fixed effects (i.e. cross-sectional R^2). R^2 is adjusted R^2. Bond controls include TTM, issue size, and indicators for bond type, insurance, callability, and putability. Econ Index is the Philadelphia Federal Reserve State Coincident Index. Housing Index is the state Case-Shiller price index. Both indices are also included on the right hand side of the regression. Maturity indicates the range of maturities used in the specification.

1.5 Cross-Sectional Differences in Pension "Seniority"

In this section, I perform additional analyses focusing on the political economy of public pensions and bond spreads. As discussed in the introduction, no clear legal framework exists defining the seniority of public pensions relative to bond debt in the event of a state fiscal crisis. Variables that proxy for the seniority of pension obligations may be informative for assessing market expectations of what a state default would look like. I first explore how cross-sectional differences in legal protections for pension liabilities affect the relationship between funding and spreads. Next, I use union membership as a proxy for pension bargaining power and thus pension seniority to further explore the political economy of pension debt. Both of these proxies are analogous to the ϕ parameter in my structural model. I use them to test Predictions 2 and 3.[25]

1.5.1 Constitutional Pension Liability Protections

Certain states provide explicit protections in their constitutions for pension liabilities. For more details, see [6]. I use the classification of [23] to define legal protections for pensions. Explicit Protection is defined as states that explicitly have clauses in their constitutions protecting pension liabilities. I also have a "Protected" flag for all states that have contract protection clauses (but not explicitly for pensions) in their state constitutions.[26] [23] argue that contract pension clauses could be applied to pension liabilities, giving them more security than in a state without such a clause. Although, it is not clear if bondholders would have the same claim under such a clause. A map of this distinction can be found in Figure 1.3. I interact these dummy variables with the unfunded pension liability to GDP ratio to understand if the effect of unfunded liabilities on spreads is stronger in states with more

25. I also tried to use political party of state governor's to proxy for pension seniority but did not find any interaction effects. This is likely due to the fact that parties are relatively constant across states over time and therefore any effects are sopped up by the state fixed effect.

26. Explicit states are: AK, AZ, HI, IL, LA, MI, NY. Protected states are all except: CT, IN, OH, ME, MN, NM, TX, WI, WY.

legal protections for these liabilities. The full specification is as follows:

$$s_{i,s,t} = \alpha_t + \alpha_s + \beta \frac{PL_{s,t} - PA_{s,t}}{GDP_{s,t}} + \psi Legal_{i,t} + \rho \frac{PL_{s,t} - PA_{s,t}}{GDP_{s,t}} \times Legal_{i,t} + \gamma' X_{s,t} + \nu' Y_{i,s,t} + \epsilon_{i,s,t} \tag{1.11}$$

where Legal is an indicator for either of the distinctions discussed above. Prediction 2 from my model implies $\psi \geq 0$, and Prediction 3 implies $\rho \geq 0$. Results from these regressions are presented in Table 1.13.

Figure 1.3: Constitutional Protections

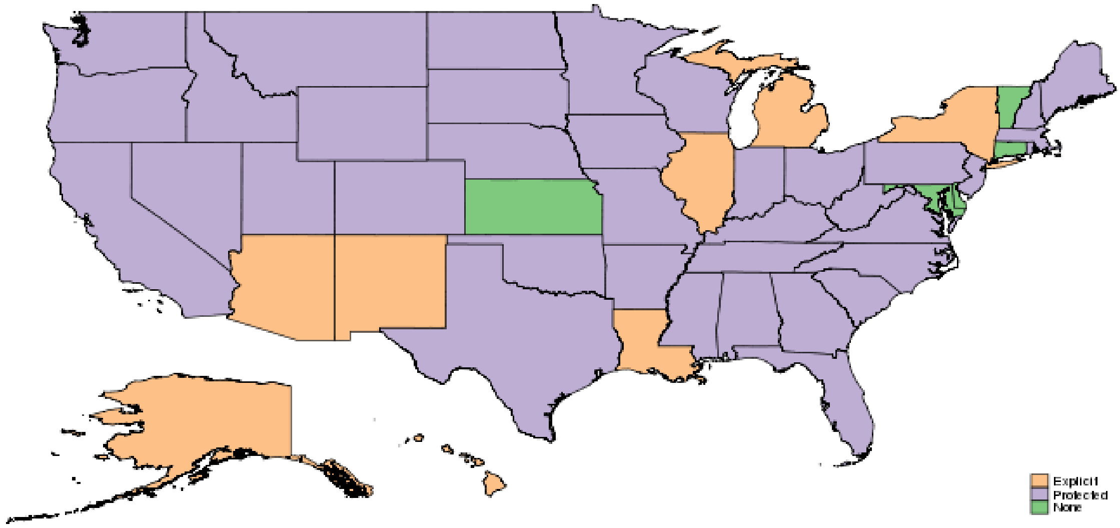

Figure 1.3 displays the constitutional protection indicator variables by state. Explicit states are states that have an explicit clause in their constitutions protecting pension liabilities. Protected states are states that have clauses generally protecting contracts under which pension liabilities should fall.

Column 1 is repeated from Table 1.5 for reference. Meanwhile, columns 2 and 3 show that states with stronger legal protections for liabilities have higher spreads. The coefficient on each legal indicator variable is positive and statistically significant. Because these classifications do not change over the sample, I cannot include state fixed effects in these regressions. These results confirm Prediction 2 of my structural model. States with some protection for pension liabilities have 15 basis point higher spreads; states with explicit protections have an *additional* increase of 66 basis points. Therefore, municipal bond markets believe these legal protections lead to a higher degree of pension seniority. The effect could work through the pension liability channel, as in my model, or independently. If the pension mechanism is at work, a given level of pension liabilities in protected states is seen as having a larger crowding out effect on bonded debt than it would be in non-protected states. Additionally, these protections could be correlated with other political/legal characteristics that make debt riskier in those states. Unfortunately, no changes in these protections exist during my sample, therefore I am unable to explore the effects of a true shock.

Interaction coefficients show the effect of unfunded pension liabilities on debt spreads is stronger in states with protections for these liabilities (columns 4 and 5), which is consistent with Prediction 3 of the structural model. Here, the state fixed effects sop up the level effect of constitutional protections. In fact, these states explain almost all of the cross-sectional relationship between spreads and pension funding. Column 5 indicates a one-standard-deviation change in the pension funding to GDP ratio is associated with a 50 basis point increase in spreads in explicitly protected states; it is only 14 basis points in non-explicitly protected states. Meanwhile, column 4 shows that in protected states this effect is 81 basis points. In fact, the effect in non-protected states is now negative, although this oddity may be driven by the fact that so few states are in the non-protected group.

These findings suggest that markets believe these legal protections do matter for forming expectations on default probabilities and recovery rates. In a state with more ”senior” pension liabilities, the government is more likely to default on bonded debt prior to missing pension payments. The increased seniority increases their default risk for a given level of pension liabilities, because these obligations have priority. That implication highlights the need for policymakers to consider the legal structure around state default and how that structure may affect borrowing conditions today along with events during a fiscal crisis.

Table 1.13: Constitutional Pension Protection and Bond Spread Regressions

	(1)	(2)	(3)	(4)	(5)
PL-PA	32.29***	10.36***	2.070	-49.27***	14.75
	(3.20)	(2.97)	(0.64)	(-3.58)	(1.31)
LTL-LTA	9.315	13.05***	13.20***	17.93***	4.895
	(1.40)	(3.04)	(3.59)	(2.91)	(0.89)
Prot.		32.04***	15.68		
		(3.01)	(1.61)		
Exp. Prot.			66.81***		
			(4.45)		
Prot. x (PL-PA)/ GDP				81.96***	
				(6.95)	
Exp. Prot. x (PL-PA)/ GDP					49.34***
					(4.67)
N	63407	63407	63407	63407	63407
R^2	0.248	0.240	0.242	0.249	0.248
Within R^2	0.122	0.130	0.132	0.122	0.122
Year FE	Yes	Yes	Yes	Yes	Yes
State FE	Yes	No	No	Yes	Yes
Bond Controls	Yes	Yes	Yes	Yes	Yes
Sample	All	All	All	All	All
Cluster	State Year	State Year	State Year	State Year	State Year

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 1.13 presents results from reduced-form regressions of annual state bond spreads over Treasuries on pension funding and other control variables. Each row indicates the numerator of the right hand side variable, which is then scaled by state-level GDP. The sample is based on annual data, where spreads are picked to match the end of fiscal years. *Rev* represents total revenue, *Exp* is total expenses, *CL* is current liabilities, *CA* is current assets, *LTA* is long-term assets, *LTL* is noncurrent liabilities, *PL* is pension liabilities, and *PA* is pension assets. *Prot.* is an indicator variable for whether or not a state has constitutional protections for pension liabilities. *Exp. Prot.* is an indicator variable for whether or not a state has explicit constitutional protections for pension liabilities. All non-dummy variables are scaled by their sample standard deviations. Thus, a coefficient represents the marginal effect of a standard deviation in the right hand side variable on the debt spread in basis points. Within R^2 is the R^2 once controlling for fixed effects (i.e. cross-sectional R^2). R^2 is adjusted R^2. Bond controls include time to maturity, issue size, and indicators for bond type, insurance, callability, and putability. Econ Index is the Philadelphia Federal Reserve State Coincident Index. Housing Index is the state Case-Shiller price index. Both indices are also included on the right hand side of the regression.

1.5.2 Union Membership and Pension Liabilities

The Detroit bankruptcy of 2013 resulted in part from an inability to renegotiate pension obligations with public unions. Legally, no set priority exists for public pension liabilities relative to bonded debt. However, unions with more power may be able to extract more resources from a government during a fiscal crisis. Moreover, states with a higher union presence may have higher general public support, which would make cutting pension benefits more politically untenable. Ex-ante, this possibility should raise default probabilities and/or loss given default for bonded debt, resulting in higher spreads. Because public pension liabilities are more senior, they would crowd out bonded liabilities, which would be consistent with Prediction 2 from the model. Thus, a given change in pension liabilities should have a larger effect on spreads in a state with more senior pensions (Prediction 3).

The BLS collects annual data on the percentage of public-sector employees in a state that are either members of or represented by a public union.[27] I use these data as a proxy for union "bargaining power" within a state.[28] It is likely to be a rough proxy, because membership does not necessarily have a one-to-one relationship with bargaining power, or a willingness to extract more value in a crisis. I argue, however, that membership is likely highly correlated with any "true" measure of the bargaining power of pensioners in a default. And this bargaining power would likely, on the margin, lead to higher recovery rates in a default event, which can be though of as analogous to having a more senior pension claim. A map of union membership in 2014 by state is presented in Figure 1.4. California, Illinois, New Jersey, and New York have some of the highest share of unionized public employees. Meanwhile, states in the deep South such as Mississippi and Georgia have lower shares. I look both at the level effect of relative union power and also the interaction with pension

27. Data is also available for private unions, along with more specific MSA-level numbers.

28. I have also looked at the state-level share of the entire population that are members of unions as a proxy for the "political power" of pensioners. Results are similar in magnitude but less significant statistically. This may indicate that the strength of a union within a pension plan is more important for seniority than the overall public opinion towards unions.

liabilities. Regression results are presented in Table 1.14.

Figure 1.4: Union Membership: 2014

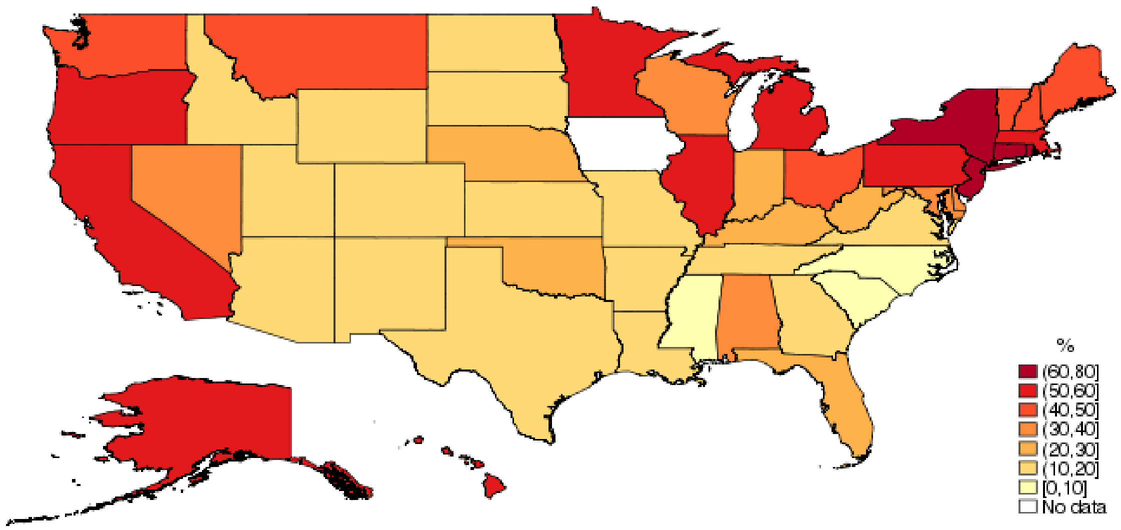

Figure 1.4 displays BLS public union membership data by state in 2014. Statistic represents the percentage of public employees who are members in a union.

Column 2 shows a positive relationship between union membership and spreads. States with a one-standard-deviation higher union membership share have a 29 basis point higher spread. Meanwhile, the coefficient on pension funding remains relatively unchanged, which suggests that states with higher union presence have higher borrowing costs. That finding is consistent with Prediction 2 of the model, though it could be for a number of reasons. Higher union membership may correlate with other variables that lead to higher credit risk in a state. Additionally, unions may be able to extract more resources from the state in good times which leads to a worse fiscal position and therefore higher default risk. Finally, markets may see union membership as a proxy for union bargaining power and assume that unions would be able to extract more in a default event.[29]

Column 3 shows a statistically significant effect of unfunded pension liabilities interacted with union membership on bond spreads. Thus, unfunded pension liabilities have a stronger

29. [11] and [12] investigate whether or not union bargaining power leads to underfunded pensions in the first place. [12] find that collective bargaining requirements significantly increase contributions to public pension plans.

effect in states with a higher union presence, again consistent with Prediction 3 of the model. Thus, I provide evidence that markets may indeed see pension liabilities as relatively more senior in these states, potentially due to increased pensioner bargaining power.

Table 1.14: Union Membership and Bond Spread Regressions

	(1)	(2)	(3)
PL-PA	32.29***	26.43**	-5.135
	(3.20)	(2.25)	(-0.36)
Exp-Rev	0.719	5.322	5.601
	(0.26)	(1.33)	(1.34)
CL-CA	-5.669	36.72*	32.12
	(-0.34)	(1.78)	(1.50)
LTL-LTA	9.315	21.66***	18.13**
	(1.40)	(2.61)	(2.02)
Union Mem. %		28.89**	15.25
		(1.99)	(1.12)
Union * (PL-PA)			12.42**
			(2.10)
N	63407	63744	63744
R^2	0.248	0.244	0.244
Within R^2	0.122	0.117	0.117
Year FE	Yes	Yes	Yes
State FE	Yes	Yes	Yes
Bond Controls	Yes	Yes	Yes
Sample	All	All	All
Cluster	State Year	State Year	State Year

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 1.14 presents results from reduced-form regressions of annual state bond spreads over Treasuries on pension funding and other control variables. Each row indicates the numerator of the right hand side variable, which is then scaled by state-level GDP. The sample is based on annual data, where spreads are picked to match the end of fiscal years. *Rev* represents total revenue, *Exp* is total expenses, *CL* is current liabilities, *CA* is current assets, *LTA* is long-term assets, *LTL* is noncurrent liabilities, *PL* is pension liabilities, and *PA* is pension assets. *Union* is the percentage of public employees who are members in a union from the BLS. All non-dummy variables are scaled by their sample standard deviations. Thus, a coefficient represents the marginal effect of a standard deviation in the right hand side variable on the debt spread in basis points. Within R^2 is the R^2 once controlling for fixed effects (i.e. cross-sectional R^2). R^2 is adjusted R^2. Bond controls include time to maturity, issue size, and indicators for bond type, insurance, callability, and putability. Econ Index is the Philadelphia Federal Reserve State Coincident Index. Housing Index is the state Case-Shiller price index. Both indices are also included on the right hand side of the regression.

This section presents evidence that investors are concerned about the relative seniority of pension liabilities in assessing default risk for state debt. Markets appear to consider legal protections as material when assessing the relative seniority of pension liabilities and determining default risk. Moreover, states with a larger union presence have higher spreads, suggesting pension liabilities are seen as more senior in these states. Taken together, these results demonstrate a unique relationship between pension liabilities and state debt spreads, which policymakers should take into account when making decisions regarding pension funding. The relationship implies that in a default event, the political process may play a large part in deciding which claims are paid out. Political and legal factors could have a large effect on the seniority of pension liabilities in a negotiation with bondholders during a fiscal crisis.

1.6 Structural Model of Municipal Debt Estimation

In this section, I revisit the model from Section 1.2 I estimate unknown parameters in the model using observed bond spreads and balance sheet data. The estimates are an important first-step in trying to understand what market prices tell us about the perceived seniority of pension debt. My goal is to observe general patterns in the level of seniority and in the cross-section in order to discern what can be learned about the relative seniority of pension and bonded debt.

1.6.1 Estimation Strategy

As a reminder, the spread on government debt from the structural model is given by:

$$s_D = -\frac{1}{T}\ln\left(1 - \frac{(P_{D+P} - P_P)}{(B_D)e^{-r_f T}}\right)$$

where P_{D+P} is the value of the put option on all government bonded debt and the senior pension liability, and P_P is the value of a put option on only the senior pension liabilities:

$$P_P = \phi B_P e^{-r_f T} N(-d_2^{\phi}) - V_A N(-d_1^{\phi})$$
$$P_{D+P} = (B_D + \phi B_P)\, e^{-r_f T} N(-d_2) - V_A N(-d_1)$$

and,

$$\begin{aligned}
d_1^{\phi} =& \frac{1}{\sigma_A \sqrt{T}} \left(\ln \left(\frac{V_A}{\phi B_P} \right) + \left(r_f + \sigma_A^2/2 \right) T \right) \\
d_2^{\phi} =& d_1^{\phi} - \sigma_A \sqrt{T} \\
d_1 =& \frac{1}{\sigma_A \sqrt{T}} \left(\ln \left(\frac{V_A}{\phi B_P + B_D} \right) + \left(r_f + \sigma_A^2/2 \right) T \right) \\
d_2 =& d_1 - \sigma_A \sqrt{T}
\end{aligned}$$

The three unknown quantities in the model are V_A, σ_A, and ϕ. The government asset value should represent the net fiscal asset of a government. That is, it should be given by the expected net present value of all future inflows minus outflows (i.e., government surpluses). The quantity is harder to conceptualize than it would be for a firm. Numerous factors could affect V_A. Although I do not observe V_A, I do observe a number of variables that correlate with V_A. We can easily see why data on demographics, politics, business climate, tax regimes, and natural resources could tell us something about the perceived net worth of a government. In Appendix A.6 I put additional structure on V_A by incorporating additional variables such as those mentioned above. Results are qualitatively and quantitatively similar to the simpler estimation I perform below.

In the main body of the paper, I estimate a set of $V_{s,t}^A, \sigma_{s,t}^A, \phi_{s,t}$ for each state/year combination in my data. For each state/year, I observe a series of year-end bond spreads over Treasuries with which I merge with static state-level information, along with the maturity of each bond. An explanation of the data I use for estimation is as follows:

1. $s_{i,s,t}$: Annual pre-tax spread over a maturity-matched Treasury for bond i, in state s in year t. Bonds are limited to GO, fixed coupon bonds without insurance or call options.

2. $B^P_{i,s,t}$: The amount of unfunded pension liabilities (liabilities - assets) in state, s, which issued bond i in year t.

3. $B^D_{i,s,t}$: The outstanding principal amount of general obligation debt in state, s, which issued bond i and at date t.

4. $T_{i,s,t}$: Time to maturity.

5. $r^f_{i,s,t}$: Maturity-matched treasury rate.

I require that a state/year combination have at least 10 valid bond observations to be included, which limits the estimation to 336 state/year combinations. I have also tried alternative definitions of B^D (e.g., all primary debt), and conclusions are insensitive to these choices.

With that data, I perform the following non-linear least-squares estimation for each/state year combination separately:

$$\min_{V^A_{s,t},\sigma^A_{s,t},\phi_{s,t}} \sum_{i,s,t} \left(s_{i,s,t} - \left(-\frac{1}{T_{i,s,t}} \ln \left(1 - \frac{(P^{D+P}_{i,s,t} - P^P_{i,s,t})}{(B^D_{i,s,t}) e^{-r^f_{i,s,t} T_{i,s,t}}} \right) \right) \right)^2 \tag{1.12}$$

At this point, it is important to understand what variation in the data identifies the estimated parameters. Each estimation is performed at the state/year level. Thus, the debt levels in the model are fixed. Therefore, the variation in the term-structure of a state's debt in a given year will be the variation used to jointly identify parameters. A steeper term structure will require a higher σ_A to match spreads. Meanwhile V_A will be pinned down by the average maturity of a state's debt along with the debt levels. The levels of debt will also matter for cross-sectional differences in estimation. For a given credit spread, a higher level of bonded debt or pension debt will require a lower ϕ parameter to match the given spread. Similarly for a fixed level of debt, a higher spread will require a higher ϕ to match the debt.[30]

1.6.2 Estimation Results

First, I present summary statistics the estimated parameters in Table 1.15. The average asset value is \$27.3 billion, which is about 5% of GDP, or 2.7 times the combined debt of a state. Substantial variation exists in this estimate, with a minimum value of \$477 million and a maximum of \$294 billion. Knowing intuitively what this variable should be is hard, because the concept of a government value is not well established. On the one hand, this number may seem low because it is much lower than the market capitalization than many Fortune 500 companies. On the other hand, a state government is in many ways a nonprofit as opposed to a for-profit corporation. Although governments have the power to raise future revenue through taxes, they also have numerous expenditures for basic government functions. Moreover, they can only raise taxes so far before they find themselves losing out on revenues as citizens leave the state.

Standard errors are displayed in the bottom panel of Table 1.15. Errors are calculated by bootstrapping each individual observation with replacement, matching the sample size of a given state/year. As the table shows, the vast majority of estimations result in a statistically significant asset value. The standard errors around the ϕ and σ_A estimates are also rather tight. The majority of the ϕ estimates are either statistically significant from 1 or 0 (i.e. do not contain both values in a 95% confidence interval). I have also run my second-stage estimations below only using significant observations and results are unchanged.

In Figure 1.5 I map the cross-section of average asset value estimates by state. The map looks intuitive. California is by far the most valuable state, with New York and Texas coming in at the top as well. Meanwhile, New Hampshire, Mississippi, and Utah are in the

30. Comparative static figures are available upon request.

Table 1.15: Parameter Estimates Summary

	Mean	StDev	Min	p_{10}	p_{25}	p_{50}	p_{75}	p_{90}	Max
$\hat{V}_A$ (bn.)	27.28	38.96	0.48	2.95	6.75	16.25	31.12	62.70	293.79
$\hat{\sigma}_A$	0.15	0.12	0.00	0.03	0.05	0.12	0.23	0.34	0.53
$\hat{\phi}$	0.61	0.42	0.00	0.00	0.00	0.85	0.98	1.00	1.00
se($\hat{V}_A$) (100 bn.)	1.36	23.89	0.00	0.00	0.01	0.02	0.04	0.09	438.56
se($\hat{\sigma}_A$)	0.06	0.04	0.00	0.02	0.03	0.05	0.07	0.10	0.24
se($\hat{\phi}$)	0.16	0.16	0.00	0.00	0.01	0.11	0.31	0.40	0.47

Table 1.15 presents summary statistics of estimates from the structural model of state government debt. Parameters are calculated from a non-linear least squares estimation of Equation 1.12. A total of 363 state/year observations generate 363 sets of the three parameters. V_A is the government asset value. σ_A is the volatility of government assets. ϕ is the seniority of pension liabilities relative to bonded debt. The bottom panel displays standard errors which are calculated by bootstrapping.

bottom of the distribution. Visually, the map provides evidence that the estimates are at least reasonable. As discussed above, the model estimates asset values close to the level of total government debt in order to generate non-zero spreads. As I mentioned above, the exact level itself may not be wholly realistic, but the cross-sectional patterns line up with *a priori* expectations. Recent work by [18] finds a negative present value of U.S. federal government surpluses. Therefore, it is not surprising that I find relatively low estimates for the present value of state government surpluses.

The estimated seniority parameters have a mean of 0.61, but a much higher median of 0.85. Many of the estimates are corner solutions, with the higher fraction being at one. Estimates may seem a bit odd at first, but they are not inherently shocking given that nothing in the data explicitly restricts ϕ to be between zero and one. One might expect a stark contrast if pension seniority is as binary as the constitutional protection variables. Again, the absolute level of these parameters is not the main goal of this exercise, but rather to think about general patterns and cross-sectional differences. For many states, the coefficient suggests that pension liabilities may not be wholly senior to bonded debt. In Figure 1.6 I show the cross-section of median ϕ estimates by state. I look at the median

Figure 1.5: Mean V_A by State

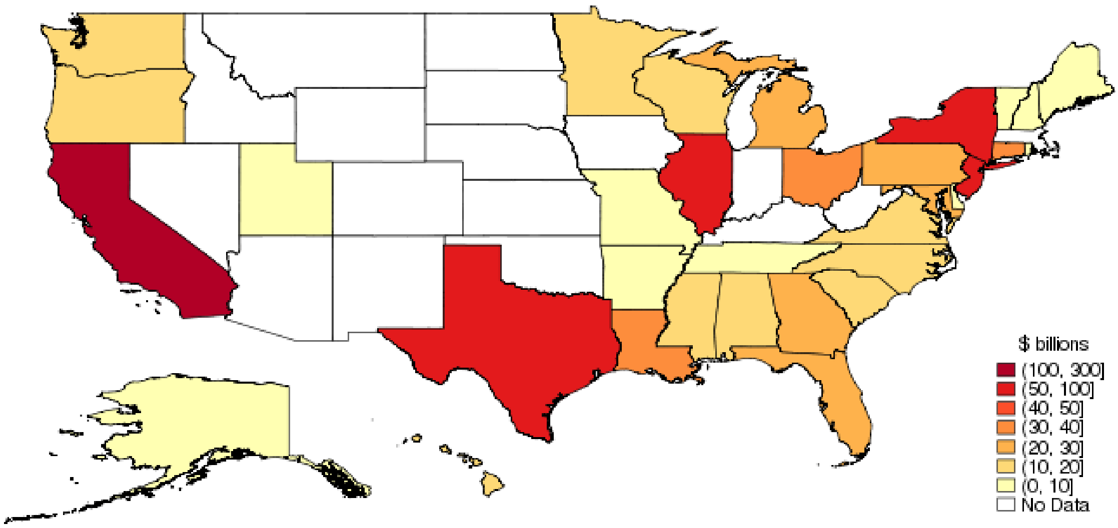

Figure 1.5 presents mean V_A estimates for each state from the estimation of Equation 1.12. States that are blank did not have any valid V_A estimates. V_A is the government asset value in the model.

as opposed to mean because although the estimates are fairly stable across time for each state, having one or two outliers out of about 15 years, which makes the means sensitive to outliers, is not uncommon. California, Louisiana, New York, New Jersey and Connecticut have high coefficients. Meanwhile, Utah, Georgia, and Florida all have much lower estimated seniority parameters. These estimates appear to line-up with my previous empirical proxies for seniority, which I fully test below.

One potential variable missing from my analysis is liquidity. If certain states' bonds are more illiquid than others (which is the case), they could bias my estimates. The map, however, suggests that this is not the case. If bonds had a liquidity premium, my model would expect a higher level of debt to meet the higher spread. Figure 1.6 shows that states such as California and New York, which are two of the most liquid states, also have the highest seniority coefficients. The liquidity channel would work in the opposite direction, which suggests it is not at play here. To be concerned about these coefficients representing an alternative factor affecting spreads, one would need to tell a story in which the states with higher seniority coefficients (i.e., require a higher level of debt in the model to match spreads), also have some other attribute that makes them riskier/have higher yields.

Figure 1.6: Median ϕ by State

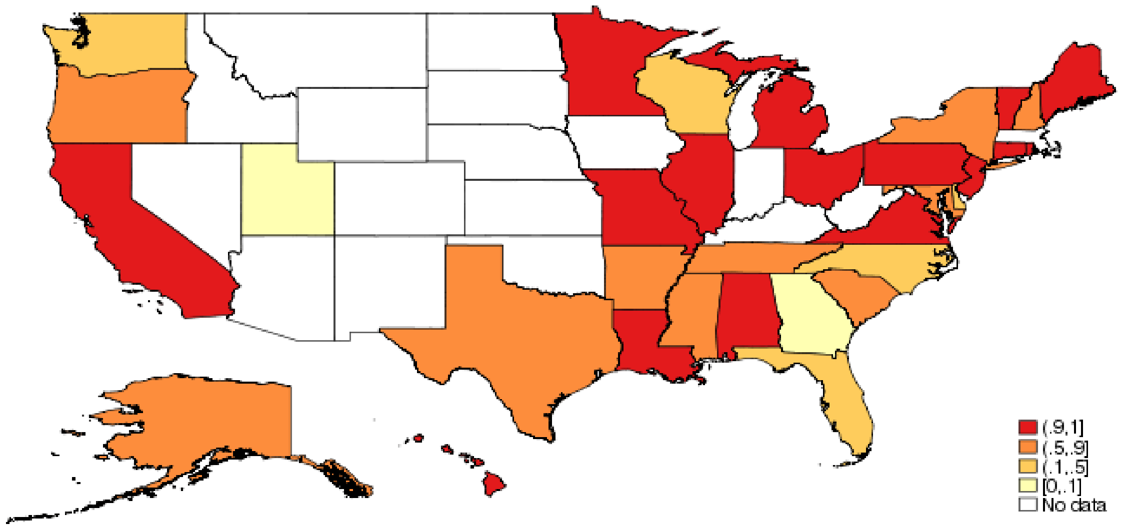

Figure 1.6 presents median ϕ estimates for each state from the estimation of Equation 1.12. States that are blank did not have any valid ϕ estimates. ϕ is the relative seniority of pension liabilities to bonded debt in the model.

Finally, I test how the estimates for pension seniority line up with my empirical proxies. I look at the two proxies, union membership and constitutional protections (which I break up into the two individual indicators), and run regressions of the estimated ϕ coefficients on these variables:

$$\hat{\phi_{s,t}} = \alpha + \beta Seniority_{s,t} + \epsilon_{s,t} \tag{1.13}$$

Results can be found in Table 1.16.

I find a positive relationship between the ϕ estimates and the seniority proxies. Both the union membership variable and protected indicator are statistically significant. Although the explicit protection variable is positive, it is not statistically significant. The lack of significance may arise from the fact that so few states have explicit protections. With the limited sample size, I do not have enough power for this regression. The results in Appendix A.6 are much stronger than those here; when I add more structure to V_A, I find all three political/legal variables have a significant relationship with ϕ. These results suggest the model finds that cross-sectional differences in seniority implied by market prices are consistent with empirical proxies I used previously. Thus, the results provide further evidence that markets are making assumptions about pension seniority when setting prices.

Column 4 includes all proxies together. The results show that union membership dominates the two legal factors. One interpretation of this result is that political factors matter more for pension seniority than legal factors. However, it is difficult to truly separate these two ideas as they are intertwined. It is quite likely that political factors lead to the implementation of legal protections. In that sense, it is perhaps not surprising that this effect dominates.

Columns 5 and 6 also include other control variables such as the size of pension liabilities, total debt, and the number of observations in the regression. This is meant to control for other factors such as liquidity, and market segmentation that may lead to a bias in results. The columns show that results are consistent when including additional controls. Finally, in column 6 I limit the estimation to ϕ parameters that are statistically different from 0 or 1 at the 95% level. This is meant to eliminate issues arising from estimations that are not well defined. Again, results are unchanged when making this adjustment.

The model estimates provide two principal take-aways. First, a number of states have non-unit pension seniority. That finding implies that in some states, pensions are not wholly senior to bonded debt. Second, significant cross-sectional variation in ϕ exists, which is consistent with my empirical proxies for pension seniority. These take-aways imply markets are factoring in seniority when setting bond prices, and seniority perceptions are consistent with various political and legal factors that could influence recovery rates in default.

Table 1.16: ϕ Estimate and Seniority Second-Stage Regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Union Membership	0.00241**			0.00211*	0.00218*	0.00285**	0.00228*
	(2.06)			(1.66)	(1.68)	(2.06)	(1.70)
Explicit		0.0289		0.0338	0.00610	0.09337	0.00580
		(0.44)		(0.50)	(0.09)	(1.22)	(0.08)
Protected			0.108*	0.0646	-0.0432	0.0756	-0.0447
			(1.69)	(0.93)	(-0.59)	(0.96)	(-0.60)
N	336	336	336	336	327	162	315
R^2	0.00963	-0.00242	0.00554	0.00788	0.145	0.261	0.145
Controls	No	No	No	No	Yes	Yes	Yes
Sample	All	All	All	All	All	$T \in [10, 20]$	Sig.

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 1.16 presents results from my second-stage ϕ estimate regressions in Equation 1.13. ϕ is the estimated pension seniority parameter. *Union membership* is the percentage of public employees who are members of unions. *Explicit* is an indicator for whether or not a state has explicit constitutional protections for pension liabilities. *Protected* is an indicator for whether or not a state has constitutional protections for pension liabilities.

1.7 Conclusion

In this paper, I find a robust and statistically significant relationship between public pension liabilities and U.S. state borrowing costs. Across U.S. states from 2005 to 2016, a one-standard-deviation increase in the ratio of unfunded pension liabilities to GDP is associated with a 27–32 basis point increase in bond spreads over the Treasury rate, about $16 - 20\%$ of the average total spread. These results are robust to controlling for state-level fiscal and economic conditions. Event study results suggest the relationship is causal. I also find this effect is stronger for bonds of longer maturities. Unfunded pensions cost U.S. states over $2 billion in lost bond issuance proceeds in 2016.

The effect of unfunded pensions liabilities on borrowing costs is significantly stronger in states with stronger legal protections for pension liabilities. Thus, I provide evidence that markets believe legal protections matter for the seniority of pension liabilities in the event of a default. Additionally, I find the effect of unfunded pension liabilities on borrowing costs is stronger in states with stronger union presence. Increased bargaining power may increase the "seniority" of pension liabilities in the event of a fiscal crisis. These results are consistent with a structural Merton-style model of government debt. Finally, estimates from the model suggest that pension liabilities may not be wholly senior to bonded debt in many states. Cross-sectional variation in investor perceptions of pension seniority are related to state-level political and legal factors.

The public pension funding crisis is not merely about future insolvency. Future obligations are already having an effect on state bond prices. Poor funding ratios are increasing borrowing costs for states, which compounds fiscal problems. Moreover, the seniority of pension liabilities is not set in stone. Markets appear to take seriously the idea that pensions may not be wholly senior to bonded debt, and that expectation is already incorporated into market prices. In the event of a state default, a political process and negotiation is likely to unfold between pensioners and debtholders, and that process will determine relative recovery rates. Policymakers and plan constituents must understand this likelihood when making fiscal and labor decisions.

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APPENDIX A

A.1 Model Proofs

As a reminder, the credit spread of debt in the model is given by:

$$s_D = -\frac{1}{T}\ln\left(1 - \frac{(P_{D+P} - P_P)}{(B_D)e^{-r_f T}}\right) \tag{A.1}$$

where P_{D+P} is the value of the put option on all government debt and the senior pension liability, and P_P is the value of a put option on only the senior pension liabilities:

$$P_P = \phi B_P e^{-r_f T} N(-d_2^{\phi}) - V_A N(-d_1^{\phi}) \tag{A.2}$$

$$P_{D+P} = (B_D + \phi B_P)\, e^{-r_f T} N(-d_2) - V_A N(-d_1) \tag{A.3}$$

where,

$$d_1^{\phi} = \frac{1}{\sigma_A \sqrt{T}}\left(\ln\left(\frac{V_A}{\phi B_P}\right) + \left(r_f + \sigma_A^2/2\right) T\right) \tag{A.4}$$

$$d_2^{\phi} = d_1^{\phi} - \sigma_A \sqrt{T} \tag{A.5}$$

$$d_1 = \frac{1}{\sigma_A \sqrt{T}}\left(\ln\left(\frac{V_A}{\phi B_P + B_D}\right) + \left(r_f + \sigma_A^2/2\right) T\right) \tag{A.6}$$

$$d_2 = d_1 - \sigma_A \sqrt{T} \tag{A.7}$$

r_f denotes the risk free rate.

The spread is derived from the following logic: The market value of debt can be thought of as the face-value of debt discounted at the market yield. Similarly, the market value of debt can be thought of as the risk-free value of the debt minus the value of protection against default. That value of protection is the difference between a put option on all government bonded debt and the senior pension liability minus the value of a put option on only the senior pension liabilities (i.e., $P_{D+P} - P_D$). Those two facts lead to the following equation:

$$\left(B_D e^{-r_f T} - (P_{D+P} - P_D)\right) = B_D e^{-yT} \tag{A.8}$$

And the credit spread is then derived as follows

$$\left(B_D e^{-r_f T} - (P_{D+P} - P_D)\right) = B_D e^{-yT} \tag{A.9}$$

$$\Rightarrow \left(B_D e^{-r_f T} - (P_{D+P} - P_D)\right) = B_D e^{-r_f T} e^{(r-y)T} \tag{A.10}$$

$$\Rightarrow \left(1 - \frac{P_{D+P} - P_D}{B_D e^{-r_f T}}\right) = e^{(r-y)T} \tag{A.11}$$

$$\Rightarrow \ln\left(1 - \frac{P_{D+P} - P_D}{B_D e^{-r_f T}}\right) = (r-y)T \tag{A.12}$$

$$\Rightarrow -\frac{1}{T}\ln\left(1 - \frac{P_{D+P} - P_D}{B_D e^{-r_f T}}\right) = y - r \tag{A.13}$$

$$\Rightarrow -\frac{1}{T}\ln\left(1 - \frac{P_{D+P} - P_D}{B_D e^{-r_f T}}\right) = s \tag{A.14}$$

(A.15)

I first derive some intermediate derivatives that I will then use in the proofs for the three predictions in Section 1.2.

$$\frac{\partial d_1^\phi}{\partial \phi} = \frac{\partial d_2^\phi}{\partial \phi} = \frac{1}{\sigma_A \sqrt{T}} \frac{\phi B_P}{V_A} \frac{-V_A}{B_P \phi^2} \tag{A.16}$$

$$= -\frac{1}{\phi \sigma_a \sqrt{T}} \leq 0 \tag{A.17}$$

and,

$$\frac{\partial d_1^{\phi}}{\partial B_P} = \frac{\partial d_2^{\phi}}{\partial B_P} = \frac{1}{\sigma_A\sqrt{T}}\frac{\phi B_P}{V_A}\frac{-V_A}{B_P\phi^2} \tag{A.18}$$

$$= -\frac{1}{B_P\sigma_a\sqrt{T}} \leq 0 \tag{A.19}$$

Meanwhile,

$$\frac{\partial d_1}{\partial \phi} = \frac{\partial d_2}{\partial \phi} = \frac{1}{\sigma_A\sqrt{T}}\frac{\phi B_P + B_D}{V_A}\frac{-V_A B_P}{(\phi B_P + B_D)^2} \tag{A.20}$$

$$= -\frac{1}{\sigma_a\sqrt{T}}\frac{B_P}{\phi B_P + B_D} \leq 0 \tag{A.21}$$

and,

$$\frac{\partial d_1}{\partial B_P} = \frac{\partial d_2}{\partial B_P} = \frac{1}{\sigma_A\sqrt{T}}\frac{\phi B_P + B_D}{V_A}\frac{-V_A \phi}{(\phi B_P + B_D)^2} \tag{A.22}$$

$$= -\frac{1}{\sigma_a\sqrt{T}}\frac{\phi}{\phi B_P + B_D} \leq 0 \tag{A.23}$$

Given that:

$$N(d_1) = \int_{-\infty}^{d_1} \frac{1}{\sqrt{2\pi}} e^{-\frac{u^2}{2}}\, du \tag{A.24}$$

$$\Rightarrow \frac{\partial N(d_1)}{\partial d_1} = \frac{1}{\sqrt{2\pi}} e^{\frac{-d_1^2}{2}} \tag{A.25}$$

and similarly,

$$\frac{\partial N(d_1^{\phi})}{\partial d_1^{\phi}} = \frac{1}{\sqrt{2\pi}} e^{\frac{\left(-d_1^{\phi}\right)^2}{2}} \tag{A.26}$$

Meanwhile,

$$\frac{\partial N(d_2)}{\partial d_2} = \frac{1}{\sqrt{2\pi}} e^{\frac{-d_2^2}{2}} \tag{A.27}$$

$$= \frac{1}{\sqrt{2\pi}} e^{\frac{-(d_1-\sigma_A\sqrt{T})^2}{2}} \tag{A.28}$$

$$= \frac{1}{\sqrt{2\pi}} e^{\frac{-d_1^2}{2}} e^{d_1\sigma_A\sqrt{T}} e^{\frac{-\sigma_A^2 T}{2}} \tag{A.29}$$

$$= \frac{1}{\sqrt{2\pi}} e^{\frac{-d_1^2}{2}} e^{\ln\left(\frac{V_A}{\phi B_P+B_D}\right)+\left(r_f+\frac{\sigma_A^2 T}{2}\right)} e^{\frac{-\sigma_A^2 T}{2}} \tag{A.30}$$

$$= \frac{1}{\sqrt{2\pi}} e^{\frac{-d_1^2}{2}} \frac{V_A}{\phi B_P + B_D} e^{r_f T} \tag{A.31}$$

and,

$$\frac{\partial N(d_2^\phi)}{\partial d_2^\phi} = \frac{1}{\sqrt{2\pi}} e^{\frac{-d_2^{\phi 2}}{2}} \tag{A.32}$$

$$= \frac{1}{\sqrt{2\pi}} e^{\frac{-\left(d_1^\phi-\sigma_A\sqrt{T}\right)^2}{2}} \tag{A.33}$$

$$= \frac{1}{\sqrt{2\pi}} e^{\frac{-d_1^{\phi 2}}{2}} e^{d_1^\phi\sigma_A\sqrt{T}} e^{\frac{-\sigma_A^2 T}{2}} \tag{A.34}$$

$$= \frac{1}{\sqrt{2\pi}} e^{\frac{-d_1^{\phi 2}}{2}} e^{\ln\left(\frac{V_A}{\phi B_P}\right)+\left(r_f+\frac{\sigma_A^2 T}{2}\right)} e^{\frac{-\sigma_A^2 T}{2}} \tag{A.35}$$

$$= \frac{1}{\sqrt{2\pi}} e^{\frac{-d_1^{\phi 2}}{2}} \frac{V_A}{\phi B_P} e^{r_f T} \tag{A.36}$$

With these basic derivatives, I can derive the first partial derivatives of P_P and P_{D+P}.

First,

$$\frac{\partial P_P}{\partial B_P} = \phi B_P e^{-r_f T} \frac{\partial N(-d_2^{\phi})}{\partial B_P} + \phi e^{-r_f T} N(-d_2^{\phi}) - V_A \frac{\partial N(-d_1^{\phi})}{\partial B_P} \tag{A.37}$$

$$= \phi B_P e^{-r_f T} \frac{\partial \left(1 - N(d_2^{\phi})\right)}{\partial B_P} + \phi e^{-r_f T} N(-d_2^{\phi}) - V_A \frac{\partial \left(1 - N(d_1^{\phi})\right)}{\partial B_P} \tag{A.38}$$

$$= -\phi B_P e^{-r_f T} \frac{\partial N(d_2^{\phi})}{\partial d_2^{\phi}} \frac{\partial d_2^{\phi}}{\partial B_P} + \phi e^{-r_f T} N(-d_2^{\phi}) + V_A \frac{\partial N(d_1^{\phi})}{\partial d_1^{\phi}} \frac{\partial d_1^{\phi}}{\partial B_P} \tag{A.39}$$

$$= -\phi B_P e^{-r_f T} \frac{1}{\sqrt{2\pi}} e^{\frac{-d_1^{\phi 2}}{2}} \frac{V_A}{\phi B_P} e^{r_f T} \left(-\frac{1}{B_P \sigma_a \sqrt{T}}\right) + \phi e^{-r_f T} N(-d_2^{\phi}) \tag{A.40}$$

$$+ V_A \frac{1}{\sqrt{2\pi}} e^{\frac{\left(-d_1^{\phi}\right)^2}{2}} \left(-\frac{1}{B_P \sigma_a \sqrt{T}}\right) \tag{A.41}$$

$$= \phi e^{-r_f T} N(-d_2^{\phi}) \tag{A.42}$$

and similarly,

$$\frac{\partial P_P}{\partial \phi} = \phi B_P e^{-r_f T} \frac{\partial N(-d_2^{\phi})}{\partial \phi} + B_P e^{-r_f T} N(-d_2^{\phi}) - V_A \frac{\partial N(-d_1^{\phi})}{\partial \phi} \tag{A.43}$$

$$= \phi B_P e^{-r_f T} \frac{\partial \left(1 - N(d_2^{\phi})\right)}{\partial \phi} + B_P e^{-r_f T} N(-d_2^{\phi}) - V_A \frac{\partial \left(1 - N(d_1^{\phi})\right)}{\partial \phi} \tag{A.44}$$

$$= -\phi B_P e^{-r_f T} \frac{\partial N(d_2^{\phi})}{\partial d_2^{\phi}} \frac{\partial d_2^{\phi}}{\partial \phi} + B_P e^{-r_f T} N(-d_2^{\phi}) + V_A \frac{\partial N(d_1^{\phi})}{\partial d_1^{\phi}} \frac{\partial d_1^{\phi}}{\partial \phi} \tag{A.45}$$

$$= -\phi B_P e^{-r_f T} \frac{1}{\sqrt{2\pi}} e^{\frac{-d_1^{\phi 2}}{2}} \frac{V_A}{\phi B_P} e^{r_f T} \left(-\frac{1}{\phi \sigma_a \sqrt{T}}\right) + B_P e^{-r_f T} N(-d_2^{\phi}) \tag{A.46}$$

$$+ V_A \frac{1}{\sqrt{2\pi}} e^{\frac{\left(-d_1^{\phi}\right)^2}{2}} \left(-\frac{1}{\phi \sigma_a \sqrt{T}}\right) \tag{A.47}$$

$$= B_P e^{-r_f T} N(-d_2^{\phi}) \tag{A.48}$$

Meanwhile,

$$\frac{\partial P_{D+P}}{\partial B_P} = (\phi B_P + B_D)\, e^{-r_f T} \frac{\partial N(-d_2)}{\partial B_P} + \phi e^{-r_f T} N(-d_2) - V_A \frac{\partial N(-d_1)}{\partial B_P} \tag{A.49}$$

$$= (\phi B_P + B_D)\, e^{-r_f T} \frac{\partial (1 - N(d_2))}{\partial B_P} + \phi e^{-r_f T} N(-d_2) - V_A \frac{\partial (1 - N(d_1))}{\partial B_P} \tag{A.50}$$

$$= -(\phi B_P + B_D)\, e^{-r_f T} \frac{\partial N(d_2)}{\partial d_2} \frac{\partial d_2}{\partial B_P} + \phi e^{-r_f T} N(-d_2) + V_A \frac{\partial N(d_1)}{\partial d_1} \frac{\partial d_1}{\partial B_P} \tag{A.51}$$

$$= -(\phi B_P + B_D)\, e^{-r_f T} \frac{1}{\sqrt{2\pi}} e^{\frac{-d_1^2}{2}} \frac{V_A}{\phi B_P + B_D} e^{r_f T} \left(-\frac{1}{\sigma_a \sqrt{T}} \right) \frac{\phi}{\phi B_P + B_D} \tag{A.52}$$

$$+ \phi e^{-r_f T} N(-d_2) \tag{A.53}$$

$$+ V_A \frac{1}{\sqrt{2\pi}} e^{\frac{(-d_1)^2}{2}} \left(-\frac{1}{\sigma_a \sqrt{T}} \right) \frac{\phi}{\phi B_P + B_D} \tag{A.54}$$

$$= \phi e^{-r_f T} N(-d_2) \tag{A.55}$$

and similarly,

$$\frac{\partial P_{D+P}}{\partial \phi} = (\phi B_P + B_D)\, e^{-r_f T} \frac{\partial N(-d_2)}{\partial \phi} + B_P e^{-r_f T} N(-d_2) - V_A \frac{\partial N(-d_1)}{\partial \phi} \tag{A.56}$$

$$= (\phi B_P + B_D)\, e^{-r_f T} \frac{\partial (1 - N(d_2))}{\partial \phi} + B_P e^{-r_f T} N(-d_2) - V_A \frac{\partial (1 - N(d_1))}{\partial \phi} \tag{A.57}$$

$$= -(\phi B_P + B_D)\, e^{-r_f T} \frac{\partial N(d_2)}{\partial d_2} \frac{\partial d_2}{\partial \phi} + B_P e^{-r_f T} N(-d_2) + V_A \frac{\partial N(d_1)}{\partial d_1} \frac{\partial d_1}{\partial \phi} \tag{A.58}$$

$$= -(\phi B_P + B_D)\, e^{-r_f T} \frac{1}{\sqrt{2\pi}} e^{\frac{-d_1^2}{2}} \frac{V_A}{\phi B_P + B_D} e^{r_f T} \left(-\frac{1}{\sigma_a \sqrt{T}} \right) \frac{B_P}{\phi B_P + B_D} \tag{A.59}$$

$$+ B_P e^{-r_f T} N(-d_2) \tag{A.60}$$

$$+ V_A \frac{1}{\sqrt{2\pi}} e^{\frac{(-d_1)^2}{2}} \left(-\frac{1}{\sigma_a \sqrt{T}} \right) \frac{B_P}{\phi B_P + B_D} \tag{A.61}$$

$$= B_P e^{-r_f T} N(-d_2) \tag{A.62}$$

Now, I can compute the first derivatives of s_D with respect to ϕ and B_P which leads to the results in Predictions 1 and 2. First,

$$\frac{\partial s_D}{\partial B_P} = -\frac{1}{T}\frac{\partial\left(1-\frac{P_{D+P}-P_P}{B_De^{-r_fT}}\right)}{\partial B_P}\left(1-\frac{P_{D+P}-P_P}{B_De^{-r_fT}}\right)^{-1} \tag{A.63}$$

$$= -\frac{1}{TB_De^{-r_fT}}\left(\frac{\partial P_P}{\partial B_P}-\frac{\partial P_{D+P}}{\partial B_P}\right)\left(1-\frac{P_{D+P}-P_P}{B_De^{-r_fT}}\right)^{-1} \tag{A.64}$$

$$= -\frac{1}{TB_De^{-r_fT}}\left(\phi e^{-r_fT}N(-d_2^{\phi})-\phi e^{-r_fT}N(-d_2)\right)\left(1-\frac{P_{D+P}-P_P}{B_De^{-r_fT}}\right)^{-1} \tag{A.65}$$

$$= -\frac{\phi}{TB_D}\left(N(-d_2^{\phi})-N(-d_2)\right)\left(1-\frac{P_{D+P}-P_P}{B_De^{-r_fT}}\right)^{-1} \tag{A.66}$$

$$= -\frac{\phi}{TB_D}\left(N(d_2)-N(d_2^{\phi})\right)\left(1-\frac{P_{D+P}-P_P}{B_De^{-r_fT}}\right)^{-1} \tag{A.67}$$

Given that $T, \phi, B_D, B_P \geq 0$, $\left(1-\frac{P_{D+P}-P_P}{B_De^{-r_fT}}\right) \in [0,1]$, and $d_2^{\phi} \geq d_2$, we have that:

$$\frac{\partial s_D}{\partial B_P} = -\frac{\phi}{TB_D}\left(N(d_2)-N(d_2^{\phi})\right)\left(1-\frac{P_{D+P}-P_P}{B_De^{-r_fT}}\right)^{-1} \geq 0 \tag{A.68}$$

which shows the result from Prediction 1. Now, for the derivative with respect to ϕ:

$$\frac{\partial s_D}{\partial \phi} = -\frac{1}{T}\frac{\partial\left(1-\frac{P_{D+P}-P_P}{B_D e^{-r_f T}}\right)}{\partial \phi}\left(1-\frac{P_{D+P}-P_P}{B_D e^{-r_f T}}\right)^{-1} \tag{A.69}$$

$$= -\frac{1}{TB_D e^{-r_f T}}\left(\frac{\partial P_P}{\partial \phi}-\frac{\partial P_{D+P}}{\partial \phi}\right)\left(1-\frac{P_{D+P}-P_P}{B_D e^{-r_f T}}\right)^{-1} \tag{A.70}$$

$$= -\frac{1}{TB_D e^{-r_f T}}\left(B_P e^{-r_f T}N(-d_2^{\phi})-B_P e^{-r_f T}N(-d_2)\right)\left(1-\frac{P_{D+P}-P_P}{B_D e^{-r_f T}}\right)^{-1} \tag{A.71}$$

$$= -\frac{B_P}{TB_D}\left(N(-d_2^{\phi})-N(-d_2)\right)\left(1-\frac{P_{D+P}-P_P}{B_D e^{-r_f T}}\right)^{-1} \tag{A.72}$$

$$= -\frac{B_P}{TB_D}\left(N(d_2)-N(d_2^{\phi})\right)\left(1-\frac{P_{D+P}-P_P}{B_D e^{-r_f T}}\right)^{-1} \tag{A.73}$$

Given that $T, \phi, B_D, B_P \geq 0$, $\left(1-\frac{P_{D+P}-P_P}{B_D e^{-r_f T}}\right) \in [0,1]$, and $d_2^{\phi} \geq d_2$, we have that:

$$\frac{\partial s_D}{\partial \phi} = -\frac{B_P}{TB_D}\left(N(d_2)-N(d_2^{\phi})\right)\left(1-\frac{P_{D+P}-P_P}{B_D e^{-r_f T}}\right)^{-1} \geq 0 \tag{A.74}$$

which proves the result from Prediction 2.

Finally, I use $\frac{\partial s_D}{\partial \phi}$ to compute the result for Prediction 3:

$$\frac{\partial s_D}{\partial \phi} = -\frac{B_P}{TB_D}\left(N(d_2)-N(d_2^{\phi})\right)\left(1-\frac{P_{D+P}-P_P}{B_D e^{-r_f T}}\right)^{-1} \tag{A.75}$$

$$\Rightarrow \frac{\partial^2 s_D}{\partial \phi \partial B_P} = \frac{\partial\left(-\frac{B_P}{TB_D}\left(N(d_2)-N(d_2^{\phi})\right)\left(1-\frac{P_{D+P}-P_P}{B_D e^{-r_f T}}\right)^{-1}\right)}{\partial B_P} \tag{A.76}$$

Let,

$$F = -\frac{B_P}{TB_D}\left(N(d_2) - N(d_2^{\phi})\right) \tag{A.77}$$

$$G = \left(1 - \frac{P_{D+P} - P_P}{B_D e^{-r_f T}}\right)^{-1} \tag{A.78}$$

$$\Rightarrow \frac{\partial^2 s_D}{\partial\phi\partial B_P} = F^{'}G + G^{'}F \tag{A.79}$$

From before we know that $G > 0$, and we also have,

$$G^{'} = \left(-\left(1 - \frac{P_{D+P} - P_P}{B_D e^{-r_f T}}\right)^{-2}\right)\frac{\partial\left(1 - \frac{P_{D+P}-P_P}{B_D e^{-r_f T}}\right)}{\partial B_P} \tag{A.80}$$

Again from before we have that,

$$\left(-\left(1 - \frac{P_{D+P} - P_P}{B_D e^{-r_f T}}\right)^{-2}\right) < 0 \tag{A.81}$$

$$\frac{\partial\left(1 - \frac{P_{D+P}-P_P}{B_D e^{-r_f T}}\right)}{\partial B_P} = \left(N(d_2) - N(d_2^{\phi})\right) < 0 \tag{A.82}$$

$$\Rightarrow G^{'} > 0 \tag{A.83}$$

And given that $d_2^{\phi} \geq d_2$, we know $F > 0$.

Combining those results with,

$$F^{'} = \frac{-1}{TB_D}\left(\left(N(d_2) - N(d_2^{\phi})\right) + B_P\left(\frac{\partial N(d_2)}{\partial B_P} - \frac{\partial N(d_2^{\phi})}{\partial B_P}\right)\right) \tag{A.84}$$

$$= \frac{-1}{TB_D}\left(\left(N(d_2) - N(d_2^{\phi})\right) + B_P\left(\frac{\partial N(d_2)}{\partial d_2}\frac{\partial d_2}{\partial B_P} - \frac{\partial N(d_2^{\phi})}{\partial d_2^{\phi}}\frac{\partial d_2^{\phi}}{\partial B_P}\right)\right) \tag{A.85}$$

and breaking it up further we have that,

$$\left(\frac{\partial N(d_2)}{\partial d_2}\frac{\partial d_2}{\partial B_P} - \frac{\partial N(d_2^\phi)}{\partial d_2^\phi}\frac{\partial d_2^\phi}{\partial B_P}\right) = \frac{1}{\sqrt{2\pi}}e^{\frac{-d_1^2}{2}}\frac{V_A}{\phi B_P + B_D}e^{r_f T}\left(-\frac{1}{\sigma_a\sqrt{T}}\frac{\phi}{\phi B_P + B_D}\right) \tag{A.86}$$

$$- \frac{1}{\sqrt{2\pi}}e^{\frac{-d_1^{\phi 2}}{2}}\frac{V_A}{\phi B_P}e^{r_f T}\left(-\frac{1}{B_P\sigma_a\sqrt{T}}\right) \tag{A.87}$$

$$= -\frac{1}{\sqrt{2\pi}}e^{\frac{-d_1^{\phi 2}}{2}}\frac{V_A e^{r_f T}}{\sigma_A\sqrt{T}}\left(\frac{\phi}{(\phi B_P + B_D)^2} - \frac{1}{\phi B_P^2}\right) \tag{A.88}$$

$$= -\frac{1}{\sqrt{2\pi}}e^{\frac{-d_1^{\phi 2}}{2}}\frac{V_A e^{r_f T}}{\sigma_A\sqrt{T}}\left(\frac{\phi^2 B_P^2 - (\phi B_P + B_D)^2}{\phi B_P^2(\phi B_P + B_D)^2}\right) \tag{A.89}$$

$$= -\frac{1}{\sqrt{2\pi}}e^{\frac{-d_1^{\phi 2}}{2}}\frac{V_A e^{r_f T}}{\sigma_A\sqrt{T}}\left(\frac{-2B_D B_P\phi - B_D^2}{\phi B_P^2(\phi B_P + B_D)^2}\right) < 0 \tag{A.90}$$

$$\Rightarrow F' > 0 \tag{A.91}$$

And all those results together show that, $\frac{\partial^2 s_D}{\partial\phi\partial B_P} \geq 0$, which proves the result from Prediction 3.

A.2 CDS Data Analysis

In this Appendix I present the main analyses using CDS spread data as opposed to bond spreads. I first describe the CDS data, and then present results

CDS Data

A credit default swap (CDS) is a derivative contract in which the buyer purchases default protection on an underlying security from a seller. The buyer makes periodic (generally quarterly or semi-annual) payments to the seller until either the end of the contract term or the arrival of a pre-specified "credit event" related to the underlying debt contract. There are two reasons CDS may alleviate some issues that exist when using bond data. First, daily CDS data are available while state bond price quotes are often stale and flat for long periods of time. Although, these are price quotes, and not actual traded prices. Bonds have numerous other features which affect spreads such as seniority, call options, and other guarantees. CDS on the other hand are standardized contracts with constant maturities which allows researchers to avoid adjusting for contractual specificities.[1] These factors could make CDS a "purer" measure of default risk, which has been highlighted in the corporate CDS literature. The state CDS market has become less liquid throughout my sample. Moreover, the 27 states with traded CDS prices are the states with more present fiscal issues which could potentially lead to a bias in the sample.

I obtain daily spreads on five-year maturity CDS obtained from Markit. I focus on the five year maturity as these are the most liquid contracts. For the regression analyses I use annual fiscal data which requires me to match an annual spread. To construct these I simply take the last daily observation in each given time period. The analysis is limited to 2005 - 2016 based on data availability. This sample size is almost double that used by [1]. Moreover,

1. The International Swaps and Derivatives Association (ISDA) sets forth standard contract terms which are used for CDS agreements. Markit uses a standardized methodology to collect quotes for prices, and interpolate to constant maturity values. I use quotes from the restructuring clause definition, which is the most traded clause for sovereign CDS.

I have a larger cross-section with 27 different states in the sample, while [1] were limited to only ten.[2]

Table A.1: Monthly State CDS Summary Statistics

	Mean	StDev.	Min	Median	Max	Serial Correlation	N
CA	109.57	96.20	5.45	77.30	396.94	0.94	148.00
MA	78.01	44.87	7.50	68.26	214.50	0.90	113.00
VA	51.66	27.63	13.00	44.33	154.00	0.87	99.00
IL	176.89	91.41	7.00	179.65	359.07	0.95	119.00
MI	113.24	75.94	29.08	80.43	356.00	0.93	110.00
AL	101.93	21.97	65.26	99.52	168.00	0.62	33.00
CT	110.74	36.40	25.00	105.86	204.62	0.72	100.00
DE	54.22	27.38	14.71	50.50	147.00	0.85	85.00
FL	78.19	47.88	11.82	56.42	220.00	0.92	112.00
GA	55.97	26.71	26.22	53.50	132.00	0.84	93.00
HI	99.00	52.79	23.00	94.17	350.00	0.79	99.00
MN	51.37	26.32	5.00	44.94	128.50	0.88	106.00
MS	103.82	22.40	36.50	106.75	182.00	0.66	101.00
MD	52.31	27.62	6.00	42.99	137.75	0.88	107.00
NJ	123.72	63.86	6.23	127.30	287.59	0.91	111.00
NV	100.58	70.20	17.74	84.19	345.00	0.93	106.00
NY	83.47	70.16	4.33	51.59	317.50	0.94	124.00
NC	53.40	29.80	7.50	45.49	145.50	0.87	103.00
OH	81.07	42.37	25.00	62.09	212.23	0.91	110.00
PA	83.13	34.92	11.50	87.75	158.50	0.90	110.00
RI	96.70	37.81	43.21	103.28	173.23	0.91	54.00
SC	55.16	31.27	10.50	42.00	143.00	0.88	107.00
TN	90.17	36.33	44.00	82.50	150.00	0.77	21.00
TX	55.22	32.88	8.00	45.04	167.50	0.91	114.00
UT	48.57	26.81	11.50	41.17	147.00	0.87	98.00
WA	66.55	34.80	19.50	67.75	153.00	0.93	94.00
WI	69.00	42.54	16.63	63.87	172.00	0.87	102.00

Table A.1 presents summary statisticss from monthly CDS data. Monthly CDS values for each state are taken from Markit as the last valid observation each month. CDS spreads are Markit quotes on the five-year maturity contract with restructuring clause. Time period covered is 2005 - 2016.

In Table A.1 I present summary statistics on monthly CDS spreads in the sample. The mean spread varies from 51.66 in Virginia to 176.89 in Illinois. California actually reached

2. States with valid data are: Alabama, California, Connecticut, Delaware, Florida, Georgi, Hawaii, Illinois, Massachusetts, Minnesota, Mississippi, Maryland, New Jersey, Nevada, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Utah, Washington, and Wisconsin.

the highest monthly spread at 396.94 basis points. Illinois has the highest median spread indicating they have had a longer period of high credit risk. The table shows significant variation in spreads as most states have standard deviations that are more than half of their means. Finally, there are large serial correlations month to month for all states. These data display a substantial amount of cross-sectional variation which warrants explanation. Moreover, the high serial correlation suggests the presence of a slow moving common factor driving spreads across states.

Figure A.1: CDS Correlation Distribution

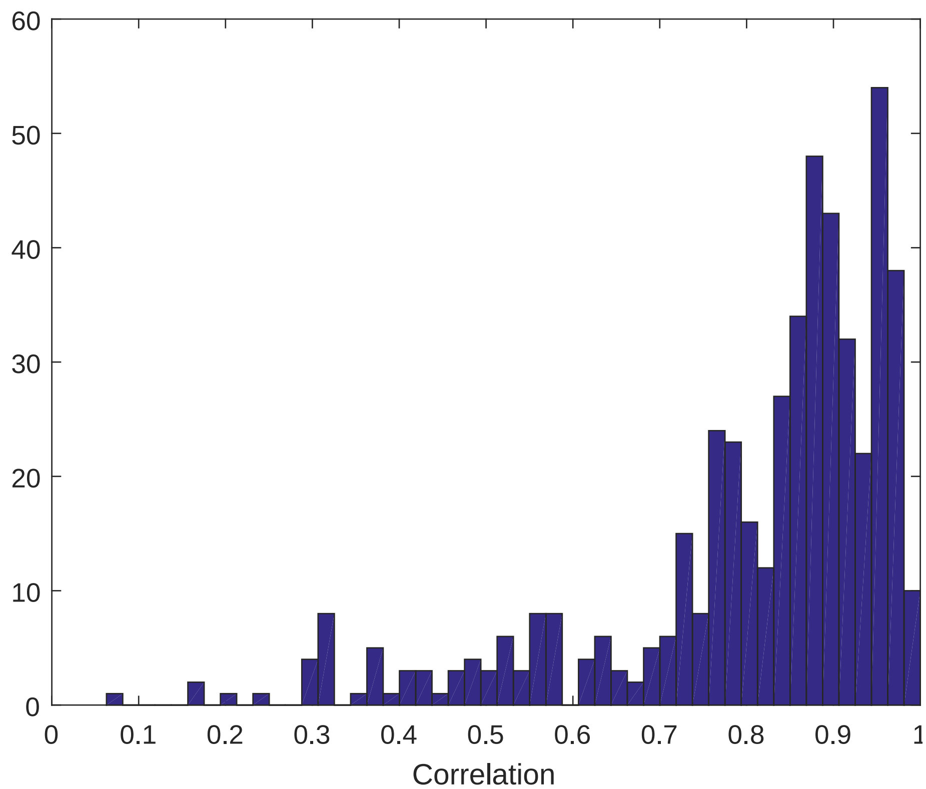

Figure A.1 presents the distribution of correlation coefficients for daily spreads for all states in the sample. Pairwise correlation coefficients are calculated using all the days for which the two states both have valid data. The distribution is based on all unique pairwise combinations.

The time-series of spreads suggests a high level of correlation between states, and I quantify these correlations in Figure A.1. This histogram plots the distribution of all unique pairs of correlations between the states. The figure shows a high degree of correlation between states. It also displays a large number of pairwise correlations that are not close to one (although none are actually negative). The average correlation is 0.8 with a standard deviation of 0.18. This implies a high degree of commonality between states. There is still sufficient deviation, however, at the state level (as also discussed in [1]) which warrants investigation.

CDS Results

Below I present the results for my principal analyses using CDS data. The results are qualitatively and quantitatively very similar to my bonded result, and for that reason I forego a detailed analysis.

Table A.2: CDS Spreads and Fiscal Ratio Regressions

	(1)	(2)	(3)	(4)
Exp-Rev	84.65***	84.65***	21.53*	21.53**
	(6.30)	(5.10)	(1.71)	(2.15)
CL-CA	45.62	45.62	54.11*	54.11
	(1.53)	(1.07)	(1.93)	(1.36)
LTL-LTA	-0.283	-0.283	12.26***	12.26**
	(-0.07)	(-0.05)	(3.57)	(2.60)
PL-PA	17.37***	17.37***	16.03***	16.03***
	(5.10)	(3.39)	(5.33)	(3.28)
N	214	214	212	212
R^2	0.352	0.352	0.616	0.616
Within R^2			0.354	0.354
Year FE	No	No	Yes	Yes
Cluster	-	State	-	State

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 1.5 presents results from reduced form regressions of annual state CDS spreads on fiscal condition variables. Each row indicates the numerator of the right hand side variable, which is then scaled by state-level GDP. The sample is based on annual data, where spreads are picked to match the end of fiscal years. *Rev* represents total revenue, *Exp* is total expenses, *CL* is current liabilities, *CA* is current assets, A is long-term assets, *LTL* is noncurrent liabilities, *PL* is pension liabilities, and *PA* is pension assets. All non-dummy variables are scaled by their sample standard deviations. Thus, a coefficient represents the marginal effect of a standard deviation in the right hand side variable on the debt spread in basis points. Columns 2 and 4 standard errors are clustered at the state level. Within R^2 is the R^2 once controlling for annual fixed effects (i.e. cross-sectional R^2). R^2 is adjusted R^2.

Table A.3: CDS Spread and Fiscal Deficit Regressions with Economic Indices

	(1)	(2)	(3)	(4)	(5)
Exp-Rev	75.01***	75.01***	21.23*	21.23*	33.88***
	(5.10)	(4.22)	(1.66)	(1.98)	(2.93)
CL-CA	43.64	43.64	53.91*	53.91	47.73
	(1.44)	(0.92)	(1.92)	(1.32)	(1.04)
LTL-LTA	1.195	1.195	12.27***	12.27**	12.01**
	(0.32)	(0.24)	(3.56)	(2.61)	(2.67)
PL-PA	15.53***	15.53***	15.86***	15.86***	14.31***
	(4.36)	(2.94)	(4.97)	(3.18)	(3.28)
Econ. Index	-7.394**	-7.394*	-0.577	-0.577	0.610
	(-2.25)	(-1.72)	(-0.17)	(-0.13)	(0.13)
Housing Index					-7.912*
					(-1.78)
N	214	214	212	212	212
R^2	0.359	0.359	0.614	0.614	0.625
Within R^2			0.351	0.351	0.369
Year FE	No	No	Yes	Yes	Yes
Cluster	-	State	-	State	State

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.3 presents results from reduced form regressions of annual state CDS spreads on fiscal condition variables. Each row indicates the numerator of the right hand side variable, which is then scaled by state-level GDP. The sample is based on annual data, where spreads are picked to match the end of fiscal years. *Rev* represents total revenue, *Exp* is total expenses, *CL* is current liabilities, *CA* is current assets, A is long-term assets, *LTL* is noncurrent liabilities, *PL* is pension liabilities, and *PA* is pension assets. All non-dummy variables are scaled by their sample standard deviations. Thus, a coefficient represents the marginal effect of a standard deviation in the right hand side variable on the debt spread in basis points. Columns 2 and 4 standard errors are clustered at the state level. Within R^2 is the R^2 once controlling for annual fixed effects (i.e. cross-sectional R^2). R^2 is adjusted R^2. Econ Index is the Philadelphia Federal Reserve State Coincident Index. Housing Index is the state Case-Shiller price index.

Table A.4: CDS Spreads and Constitutional Pension Protections

	(1)	(2)	(3)	(4)
Exp-Rev	21.53**	21.95*	13.45	21.66*
	(2.15)	(1.78)	(1.27)	(2.02)
CL-CA	54.11	62.44	50.09	73.30*
	(1.36)	(1.56)	(1.39)	(1.71)
LTL-LTA	12.26**	11.89**	12.32**	13.62**
	(2.60)	(2.61)	(2.75)	(2.67)
PL-PA	16.03***	14.11***	11.79**	-2.103
	(3.28)	(3.49)	(2.45)	(-0.24)
Exp. Prot. x (PL-PA)/ GDP			11.67	
			(1.64)	
Prot. x (PL-PA)/ GDP				19.13**
				(2.23)
N	212	212	212	212
R^2	0.616	0.648	0.634	0.636
Within R^2	0.354	0.409	0.386	0.389
Year FE	Yes	Yes	Yes	Yes
State FE				
Cluster	State	State	State	State

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.4 presents results from reduced form regressions of annual state CDS spreads on fiscal condition variables. Each row indicates the numerator of the right hand side variable, which is then scaled by state-level GDP. The sample is based on annual data, where spreads are picked to match the end of fiscal years. *Rev* represents total revenue, *Exp* is total expenses, *CL* is current liabilities, *CA* is current assets, A is long-term assets, *LTL* is noncurrent liabilities, *PL* is pension liabilities, and *PA* is pension assets. *Exp. Prot.* is an indicator variable for whether or not a state has explicit constitutional protections for pension liabilities. *Prot.* is an indicator variable for whether or not a state has constitutional protections for pension liabilities. All non-dummy variables are scaled by their sample standard deviations. Thus, a coefficient represents the marginal effect of a standard deviation in the right hand side variable on the debt spread in basis points. Columns 2 and 4 standard errors are clustered at the state level. Within R^2 is the R^2 once controlling for annual fixed effects (i.e. cross-sectional R^2). R^2 is adjusted R^2.

A.3 Government Data Construction Detail

There is currently a lack of readily available panel data on state level finances. The only currently available source is the US Census State Finances data. Each year the Census asks state governments by survey to fill in a number of accounting variables, which are then compiled by the Census Bureau. Each state has responded historically, so there is not a response bias. The Census focuses primarily on revenue and expense variables. While these values capture government flows, they do not collect the stock balance sheet information in a comprehensive manner. Under a structural framework, it is the balance sheet which is most important for understanding spreads. More broadly, state leverage information is vital for understanding fiscal health across states. Thus, I construct a more detailed dataset of state government finances in which I focus on balance sheet variables.

Each year, state governments release a Comprehensive Annual Financial Report (CAFR). These reflect state government fiscal years that end June 30.[3] These 10-K like reports include a Statement of Net Position and Statement of Activities which are balance sheet, and income statement equivalents. I use primarily these two statements to construct the fiscal data. I focus on 2002-2016 as beginning in 2002 GASB required a more standardized CAFR format.

I collect information on revenues, taxes, expenses, assets, liabilities and debt. In addition to total revenues and expenses I capture detailed breakdowns of tax revenues. I split taxes into personal income taxes, corporate income taxes, sales taxes, insurance taxes, property taxes, motor vehicle taxes, and other. Unfortunately, certain states have varying levels of granularity in reporting taxes, including some who do not provide easy to decipher breakdowns. As such, I do not focus on these variables in this work.

I also break down assets into current, non-current and capital assets. Capital assets include government buildings and infrastructure which generally is not allowed to be sold. Thus, these assets may not be relevant for debt pricing given their inability to meet liability

3. The only exceptions are the following: Alabama, Michigan (Sep. 30), New York (March 31), and Texas (Aug. 31).

needs. Net assets captures assets minus liabilities for both restricted and unrestricted assets. Certain government assets are restricted for certain purposes, thus states report restricted assets and net assets in these two categories.

Finally, I collect more detailed information on state outstanding debt. In addition to capturing the total amount of debt outstanding each year, I break it out into the following categories: general obligation bonds, revenue bonds, limited obligation bonds, capital leases, and certificates of participation. Again, states have some variance in how they report this debt, and therefore at this point I do not do any analysis on the breakdown of debt types. Details on the specific ratios I use in my analysis can be found in the main body of the paper.

In the next three pages I copy the Statement of Net Position and Activities from the 2015 Massachusetts CAFR. The first two pages are the Statement of Net Position. The Government Wide column contains the line-items I enter into the data. I collect the large items such as current/noncurrent assets and liabilities. I do, however, collect some more detailed information on current assets with items such as cash (the sum of the first two line items), total receivables, and investments. Moreover, I collect the net asset numbers from the second page of the CAFR. This includes collecting capital asset numbers separately along with restricted and unrestricted items.

Meanwhile, the third page of the included CAFR is the equivalent of a income statement. I collect total revenue and expense numbers, along with detailed information on taxes from the final page of the document. Certain CAFRs are not quite as clear-cut as this example. For some, current vs. non-current assets/liabilities are not broken up into separate totaled line items. In this case I have to add line items manually to arrive at a number. Additionally, some states do not break down tax revenues, and thus I can only obtain total tax receipt numbers for those states. I try to stay as consistent as possible in using the same sub-items for each variable across states. This is also true of my collection of outstanding debt figures, as some states have different naming conditions for bonds. More detailed information on a state by state basis is available upon request.

Statement of Net Position

June 30, 2015

(Amounts in thousands)

	Primary Government			
	Governmental Activities	Business-Type Activities	Government Wide Total	Component Units
ASSETS AND DEFERRED OUTFLOWS				
Current assets:				
Cash, cash equivalents and short-term investments	$ 3,206,633	$ 1,010,314	$ 4,216,947	$ 2,842,328
Cash with fiscal agent	197,836	—	197,836	—
Assets held in trust	—	—	—	148,066
Receivables, net of allowance for uncollectibles:				
Taxes	3,084,006	—	3,084,006	—
Federal grants and reimbursements receivable	2,135,280	100,702	2,235,982	155,141
Loans	8,998	47,616	56,614	424,108
Other receivables	435,791	549,743	985,534	305,440
Due from cities and towns	19,722	—	19,722	—
Due from component units	488	383	871	—
Due from primary government	—	—	—	689,469
Other current assets	—	51,711	51,711	57,046
Total current assets	9,088,754	1,760,469	10,849,223	4,621,598
Noncurrent assets:				
Cash and cash equivalents - restricted	—	752,683	752,683	855,081
Long-term investments	—	914,457	914,457	1,708,327
Investments, restricted investments and annuity contracts	2,662,627	843	2,663,470	165,392
Receivables, net of allowance for uncollectibles:				
Taxes	463,648	—	463,648	—
Federal grants and reimbursements receivable	48,735	—	48,735	—
Loans	101,218	9,292	110,510	4,199,099
Other receivables	43,757	47,909	91,666	22,147
Due from component units	9,508	—	9,508	—
Non-depreciable capital assets	1,822,239	878,231	2,700,470	8,905,874
Depreciable capital assets, net	2,780,083	5,805,985	8,586,068	25,247,444
Other noncurrent assets	—	20,955	20,955	36,894
Other noncurrent assets - restricted	—	1,008,476	1,008,476	—
Total noncurrent assets	7,931,815	9,438,831	17,370,646	41,140,258
Deferred outflows of resources:				
Deferred change in fair value of interest rate swaps	329,833	46,111	375,944	241,180
Deferred loss on refunding	142,805	114,672	257,477	363,301
Deferred outflows related to pension	1,827,615	74,097	1,901,712	163,903
Total deferred outflows of resources	2,300,253	234,880	2,535,133	768,384
Total assets and deferred outflows	19,320,822	11,434,180	30,755,002	46,530,240
LIABILITIES AND DEFERRED INFLOWS				
Current liabilities:				
Accounts payable and other liabilities	3,314,917	280,168	3,595,085	1,156,283
Accrued payroll	212,696	200,958	413,654	1,946
Compensated absences	371,870	146,271	518,141	26,739
Accrued interest payable	367,821	22,915	390,736	221,782
Tax refunds and abatements payable	1,058,406	46,600	1,105,006	—
Due to component units	637,298	224	637,522	—
Due to primary government	—	—	—	871
Due to federal government	24,504	—	24,504	—
Claims and judgments	11,819	—	11,819	—
Unearned revenue	—	22,665	22,665	308,721

Statement of Net Position

June 30, 2015

(Amounts in thousands)

	Primary Government			
	Governmental Activities	Business-Type Activities	Government Wide Total	Component Units
Deposits and unearned revenue	—	74,510	74,510	—
School construction grants payable	357,100	—	357,100	—
Capital leases	7,876	2,471	10,347	4,569
Massachusetts School Building Authority notes payable	435,000	—	435,000	—
Massachusetts School Building Authority bonds and unamortized premiums	173,529	—	173,529	—
Bonds payable and unamortized premiums	1,743,338	250,229	1,993,567	739,773
Environmental remediation liability	10,932	11	10,943	—
Total current liabilities	8,727,106	1,047,022	9,774,128	2,460,684
Noncurrent liabilities:				
Compensated absences	205,446	66,729	272,175	21,598
Accrued interest payable	—	—	—	215,127
Due to primary government	—	—	—	9,508
Due to federal government - grants	—	10,692	10,692	—
Unearned revenue	—	—	—	38,722
Prizes payable	1,243,000	—	1,243,000	—
Capital leases	35,052	7,424	42,476	61,246
Bonds payable and unamortized premiums	23,047,571	4,302,876	27,350,447	10,944,888
Massachusetts School Building Authority bonds and unamortized premiums	6,027,865	—	6,027,865	—
School construction grants payable	723,919	—	723,919	—
Environmental remediation liability	197,047	—	197,047	—
Liability for derivative instruments	329,833	72,517	402,350	483,309
Net pension liability	24,531,950	403,393	24,935,343	1,399,888
Post-employment benefits obligations (other than pensions)	5,605,000	—	5,605,000	856,556
Other noncurrent liabilities	468,795	120,314	589,109	228,974
Total noncurrent liabilities	62,415,478	4,983,945	67,399,423	14,259,816
Deferred inflows of resources:				
Deferred service concession arrangements	—	16,923	16,923	—
Deferred inflows related to pension	2,969,528	90,883	3,060,411	82,917
Deferred gain on refunding	62,151	122	62,273	300
Governmental voluntary nonexchange transactions	—	3,000	3,000	—
Total deferred inflows of resources	3,031,679	110,928	3,142,607	83,217
Total liabilities and deferred inflows	74,174,263	6,141,895	80,316,158	16,803,717
NET POSITION				
Net investment in capital assets	(553,272)	3,055,444	2,502,172	27,480,236
Restricted for:				
Unemployment benefits	—	1,320,347	1,320,347	—
Retirement of indebtedness	1,164,045	—	1,164,045	—
Higher education endowment funds	—	18,920	18,920	—
Higher education academic support and programs	—	2,961	2,961	—
Higher education scholarships and fellowships:				
Nonexpendable	—	3,553	3,553	—
Expendable	—	6,442	6,442	—
Other nonexpendable purposes	—	3,536	3,536	—
Capital projects - expendable purposes	—	2,206	2,206	—
Other purposes	377,521	181,820	559,341	3,772,412
Unrestricted (deficits)	(55,841,735)	697,056	(55,144,679)	(1,526,125)
Total net position	$ (54,853,441)	$ 5,292,285	$ (49,561,156)	$ 29,726,523

The notes to the financial statements are an integral part of this statement. (concluded)

Statement of Activities

Fiscal Year Ended June 30, 2015

(Amounts in thousands)

Functions/Programs	Expenses	Program Revenues			Net (Expenses) Revenues and Changes in Net Assets — Primary Government			
		Charges for Services	Operating Grants and Contributions	Capital Grants and Contributions	Governmental Activities	Business-Type Activities	Total	Component Units
Primary government:								
Governmental Activities:								
General government	$ 2,703,519	$ 634,289	$ 643,770	$ —	$ (1,425,460)	$ —	$ (1,425,460)	$ —
Judiciary	1,026,429	105,521	1,213	—	(919,695)	—	(919,695)	—
Direct local aid	5,469,412	—	—	—	(5,469,412)	—	(5,469,412)	—
Medicaid	15,086,742	1,052,170	8,709,401	80,237	(5,244,934)	—	(5,244,934)	—
Group health insurance	1,657,018	755,712	—	—	(901,306)	—	(901,306)	—
Energy and environmental affairs	671,801	253,856	496,978	—	79,033	—	79,033	—
Housing and economic development	1,314,980	164,438	56,780	—	(1,093,762)	—	(1,093,762)	—
Health and human services	7,605,180	405,710	2,499,315	—	(4,700,155)	—	(4,700,155)	—
Transportation and public works	2,689,975	577,430	217	1,238	(2,111,090)	—	(2,111,090)	—
Early elementary and secondary education	4,654,161	7,649	1,192,664	—	(3,453,848)	—	(3,453,848)	—
Public safety and homeland security	2,486,107	256,596	178,224	—	(2,051,287)	—	(2,051,287)	—
Labor and workforce development	309,091	175,130	171,665	—	37,704	—	37,704	—
Lottery	4,109,611	5,193,545	—	—	1,083,934	—	1,083,934	—
Interest (unallocated)	1,263,218	—	—	—	(1,263,218)	—	(1,263,218)	—
Total governmental activities	**51,047,244**	**9,582,046**	**13,950,227**	**81,475**	**(27,433,496)**	**—**	**(27,433,496)**	**—**
Business-Type Activities:								
Unemployment Compensation	1,598,084	1,492,067	59,941	—	—	(46,076)	(46,076)	—
Higher Education:								
University of Massachusetts	2,809,062	1,602,043	517,360	62,582	—	(627,077)	(627,077)	—
State Universities	994,341	583,671	105,881	104,146	—	(200,643)	(200,643)	—
Community Colleges	891,906	266,956	253,735	39,400	—	(331,815)	(331,815)	—
Total business-type activities	**6,293,393**	**3,944,737**	**936,917**	**206,128**	**—**	**(1,205,611)**	**(1,205,611)**	**—**
Total primary government	**$ 57,340,637**	**$ 13,526,783**	**$ 14,887,144**	**$ 287,603**	**(27,433,496)**	**(1,205,611)**	**(28,639,107)**	**—**
Component Units:								
Massachusetts Department of Transportation	$ 5,485,652	$ 1,419,950	$ 2,122,152	$ 3,087,321	—	—	—	$ 1,143,771
Commonwealth Health Insurance Connector	576,085	501,008	80,436	—	—	—	—	5,359
Massachusetts Clean Water Trust	148,939	154,534	30,375	76,099	—	—	—	112,069
Other nonmajor component units	513,557	388,965	107,169	(54,708)	—	—	—	(72,131)
Total component units	**$ 6,724,233**	**$ 2,464,457**	**$ 2,340,132**	**$ 3,108,712**	**—**	**—**	**—**	**1,189,068**

(continued)

General revenues:	Primary Government Governmental Activities	Business-Type Activities	Total	Component Units
Taxes:				
Income	14,326,957	—	14,326,957	—
Sales taxes	5,832,151	—	5,832,151	—
Corporate taxes	2,264,787	—	2,264,787	—
Motor and special fuel taxes	757,503	—	757,503	—
Other taxes	2,028,428	—	2,028,428	—
Miscellaneous:				
Investment earnings/(loss)	26,972	(132,238)	(105,266)	4,751
Tobacco settlement	241,025	—	241,025	—
Contribution from municipalities	61,991	—	61,991	—
Other revenue	921,205	139,774	1,060,979	234,170
Transfers	(1,429,174)	1,429,174	—	—
Total general revenues and transfers	**25,031,845**	**1,436,710**	**26,468,555**	**238,921**
Change in net position	**(2,401,651)**	**231,099**	**(2,170,552)**	**1,427,989**
Net position (deficits) - beginning, as restated	(52,451,790)	5,061,186	(47,390,604)	28,298,534
Net position (deficits) - ending	**$ (54,853,441)**	**$ 5,292,285**	**$ (49,561,156)**	**$ 29,726,523**

The notes to the financial statements are an integral part of this statement.

(concluded)

A.4 Alternate Liability Discounting Results

In this Appendix I present robustness results from my main reduced-form specifications using alternate pension liability discounting methods.

[27] highlight that public pension plans generally discount their pension liabilities at the expected rate of return on their assets in accordance with GASB 25. The vast majority of plans in my database use 8% for discounting future liabilities. [27] point out that given the security of these liabilities it may be more reasonable to discount them at the yield of GO bonds within a state, or even the risk-free rate. I use a shorthand method of adjusting my main specification for these alternate discount assumptions. For each liability figure, I scale that number by the ratio of reported liabilities to liabilities discounted at different rates from Table 4 of [27]. While this will not pick up time-series variation in the relationship, it is an implementable strategy to check how my results may be affected by differing discount rates. As the results show, my main conclusions and quantitative estimates are unchanged by this analysis.

Table A.5: Bond Debt Spreads Regression Results - Risk Free Discounting

	(1)	(2)	(3)	(4)
PL-PA (Risk-Free)	17.55***	47.18***	42.79***	42.28***
	(4.39)	(3.61)	(3.58)	(3.39)
Exp-Rev	2.876	3.804	-0.561	-2.073
	(0.71)	(0.94)	(-0.19)	(-0.72)
CL-CA	5.160***	42.73**	-4.680	-26.38
	(2.94)	(2.12)	(-0.27)	(-1.24)
LTL-LTA	10.60**	20.47***	8.587	3.871
	(2.39)	(2.73)	(1.35)	(0.51)
N	64139	64139	63407	48018
R^2	0.240	0.245	0.248	0.277
Within R^2	0.129	0.117	0.122	0.135
Year FE	Yes	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Bond Controls	Yes	Yes	Yes	Yes
Sample	All	All	All	GO
Cluster	State Year	State Year	State Year	State Year

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.5 presents results from reduced-form regressions of annual state bond spreads over Treasuries on pension funding and other control variables. Each row indicates the numerator of the right hand side variable, which is then scaled by state-level GDP. The sample is based on annual data, where spreads are picked to match the end of fiscal years. *Rev* represents total revenue, *Exp* is total expenses, *CL* is current liabilities, *CA* is current assets, *LTA* is long-term assets, *LTL* is noncurrent liabilities, *PL* is pension liabilities, and *PA* is pension assets. Pension liabilities are adjusted to be discounted at a risk-free rate. All non-dummy variables are scaled by their sample standard deviations. Thus, a coefficient represents the marginal effect of a standard deviation in the right hand side variable on the debt spread in basis points. Within R^2 is the R^2 once controlling for fixed effects (i.e. cross-sectional R^2). R^2 is adjusted R^2. Bond controls include time to maturity, issue size, and indicators for bond type, insurance, callability, and putability. Econ Index is the Philadelphia Federal Reserve State Coincident Index. Housing Index is the state Case-Shiller price index. Both indices are included in each specification.

Table A.6: Bond Debt Spreads Regression Results - Muni Bond Discounting

	(1)	(2)	(3)	(4)
PL-PA (Muni)	10.08*	25.48*	36.78***	29.52**
	(1.71)	(1.65)	(2.77)	(2.48)
Exp-Rev	3.604	4.568	0.119	-1.052
	(0.87)	(1.18)	(0.04)	(-0.35)
CL-CA	2.182	40.47**	-8.116	-30.90
	(1.09)	(1.98)	(-0.47)	(-1.44)
LTL-LTA	12.93**	25.12***	9.492	7.489
	(2.54)	(3.01)	(1.38)	(0.93)
N	64139	64139	63407	48018
R^2	0.239	0.245	0.248	0.277
Within R^2	0.128	0.117	0.121	0.135
Year FE	Yes	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Bond Controls	Yes	Yes	Yes	Yes
Sample	All	All	All	GO
Cluster	State Year	State Year	State Year	State Year

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.6 presents results from reduced-form regressions of annual state bond spreads over Treasuries on pension funding and other control variables. Each row indicates the numerator of the right hand side variable, which is then scaled by state-level GDP. The sample is based on annual data, where spreads are picked to match the end of fiscal years. *Rev* represents total revenue, *Exp* is total expenses, *CL* is current liabilities, *CA* is current assets, *LTA* is long-term assets, *LTL* is noncurrent liabilities, *PL* is pension liabilities, and *PA* is pension assets. Pension liabilities are adjusted to be discounted at the general obligation interest rate for each state. All non-dummy variables are scaled by their sample standard deviations. Thus, a coefficient represents the marginal effect of a standard deviation in the right hand side variable on the debt spread in basis points. Within R^2 is the R^2 once controlling for fixed effects (i.e. cross-sectional R^2). R^2 is adjusted R^2. Bond controls include time to maturity, issue size, and indicators for bond type, insurance, callability, and putability. Econ Index is the Philadelphia Federal Reserve State Coincident Index. Housing Index is the state Case-Shiller price index. Both indices are included in each specification.

A.5 Tax Revenue Analysis

In this appendix I present results from an analysis of the effects of tax revenue streams on bond spreads. Once concern with the main specification in Section 1.4, is that I am not properly controlling for state revenue streams. The ability to meet debt payments is heavily dependent on a state's ability to raise taxes. Different states have different tax structures that could have an effect on the ability to raise taxes in the future. Some states rely heavily on income taxes, while others rely on property taxes for revenue. It is quite possible the elasticity of residents to taxes may depend on the type of tax levied. Moreover, the tax rates of neighboring states may play a role in a states' ability to raise revenue. Residents who can easily move to a state with lower taxes may be more sensitive to changes in rates.

In Table A.7 I add additional information on tax revenues to investigate the relationship between tax regimes and borrowing costs. I include the ratio of income taxes to GDP (*Inc. Tax/GDP*), the ratio of property taxes to GDP (*Prop. Tax/GDP*), and the fraction of total tax revenue composed of income taxes *Inc. Tax/Tot. Tax*. I also include a variable (*Neighbor Tax. Dif.*) meant to capture the sensitivity of residents to tax rates. This is calculated as the difference between the top marginal tax-rate in a state, and the average marginal rate in all neighboring states. One might expect the higher the difference, the less ability the state has to raise taxes, which should result in higher borrowing costs.

The results show that estimates of the relationship between unfunded pension liabilities and bond spreads are not biased by excluding these tax variables. The coefficient on *PL-PA* is unchanged and statistically significant. Of the additional variables, only *Prop. Tax/GDP* has a statistically significant relationship with bond spreads. A one-standard-deviation increase in this ratio is associated with a 67 basis point decrease in spreads. This may be closely related to the fact that the housing index also has a significant negative coefficient. Both variables are an indicator of the performance of the housing market in a state, and are likely to have a strong correlation with the ability to raise revenues. First, this implies that increased property tax revenues reduces the default risk of states by improving fiscal conditions which leads to lower spreads. Second, the large magnitude suggests that states may not be close to the point where higher property taxes lead to emigration, a decreace in the tax base, and higher default risk. Further research should look at the role of housing, and property taxes on municipal bond yields.

Table A.7: Tax Revenue Analysis Regressions

	(1)	(2)	(3)
PL-PA	32.29***	38.67***	31.16***
	(3.20)	(3.65)	(3.35)
Inc. Tax / GDP		3.914	-6.589
		(0.12)	(-0.24)
Prop. Tax / GDP		-81.92***	-67.37***
		(-3.50)	(-3.37)
Inc. Tax / Tot. Tax		-14.50	-0.860
		(-0.46)	(-0.04)
Neighbor Tax Dif.		-5.278	-4.394
		(-0.93)	(-0.86)
N	63407	61428	46184
R^2	0.248	0.244	0.272
Within R^2	0.122	0.120	0.133
Year FE	Yes	Yes	Yes
State FE	Yes	Yes	Yes
Bond Controls	Yes	Yes	Yes
Sample	All	All	GO
Cluster	State Year	State Year	State Year

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.7 presents results from reduced-form regressions of annual state bond spreads over Treasuries on pension funding and other control variables. Each row indicates the numerator of the right hand side variable, which is then scaled by state-level GDP. The sample is based on annual data, where spreads are picked to match the end of fiscal years. *Rev* represents total revenue, *Exp* is total expenses, *CL* is current liabilities, *CA* is current assets, *LTA* is long-term assets, *LTL* is noncurrent liabilities, *PL* is pension liabilities, and *PA* is pension assets. (*Inc. Tax/GDP*) is the ratio of income tax revenue to GDP. (*Prop. Tax/GDP*) is the ratio of property tax revenue to GDP. *Inc. Tax/Tot. Tax* is the ratio of income tax revenue to total tax revenue. (*Neighbor Tax. Dif.*) is the difference between the top-marginal tax-rate and the average top rate of all neighboring states. All non-dummy variables are scaled by their sample standard deviations. Thus, a coefficient represents the marginal effect of a standard deviation in the right hand side variable on the debt spread in basis points. Within R^2 is the R^2 once controlling for fixed effects (i.e. cross-sectional R^2). R^2 is adjusted R^2. Bond controls include time to maturity, issue size, and indicators for bond type, insurance, callability, and putability. Econ Index is the Philadelphia Federal Reserve State Coincident Index. Housing Index is the state Case-Shiller price index. Both indices are included in all specifications.

A.6 Alternative Model Estimation

In this Appendix I perform an alternative estimation of the model in Section 1.6. Results are qualitatively and quantitatively similar to those in the main body of the paper. Here, I add more structure to the V_A parameter in my model. This serves two purposes: it provides a robustness check on my main estimation and also provides a more intuitive interpretation of the V_A estimates.

The government asset value should represent the net fiscal asset of a government. That is, it should be given by the expected net present value of all future inflows minus outflows. This is a harder concept to conceptualize than it would be for a firm. There are numerous factors that could affect V_A. While I do not observe V_A, I do observe a number of factors that may contribute to V_A. It is not difficult to see why data on demographics, politics, business climate, tax regimes, and natural resources could tell us something about the perceived net worth of a government. Therefore, to aid in a more realistic interpretation of my results, I also add the following structure to my model:

$$V_A^{s,t} = A + BX_{s,t} \tag{A.92}$$

I assume the asset value of government s at time t, is a linear function of a number of characteristics of the state $X_{s,t}$. I assume this linear relationship is constant across states and time (i.e. B is static). This is partly for parsimony but also estimation simplicity. I am not stating that this linear structure is exactly how one should think about the relationship between these variables and government asset value. Rather, it is a simple modification to provide more structure to the model in a straightforward manner. It also adds an additional level of interest to my estimation output as I will be able to explore the relationship between certain variables and the estimated government value. It will also ensure that financial market variables are not the only inputs in determining the asset value of a government, which is likely not a value investors are directly estimating when setting prices.

The following are the variables I use in my $X_{s,t}$: GDP, Case-Shiller Home Price Index, Natural Resource Revenue, Land Size, Republican Tilt (from Gallup surveys), Education Level (pct. of population with Bachelor Degree), and Tax Rate Difference (the difference between the state's top marginal tax rate, and the average rate of all neighboring states). This is an incomplete list; there are many other variables that may independently impact government value. My goal, however, is not to have a complete model. Rather, I aim to have a parsimonious set of variables that can provide a substantial amount of information correlated with government asset value. As such, this will put more structure on my model which will lead to more intuitive output for this parameter. Below are more details on this data:

1. GDP: Annual State GDP in nominal dollars from the BEA.
2. HPI: S&P Case-Shiller Home Price Index by state. Matched with end of month of fiscal year.
3. Natural Resource Revenue: Annual revenue from natural resources by state from the DOI.
4. Land Size: Total area in square miles from the U.S. Census Bureau.
5. Republican Tilt: Difference between the percentage of citizens identifying as Republicans and percentage identifying as Democrats. From Gallup Polls.
6. Education: Percentage of citizens by state with a bachelors degree from U.S. Census.
7. Tax Difference: The difference between the top state marginal tax rate and the average rate of all adjoining states. Marginal tax rates from the NBER.

The additional data used in the estimation is as follows:

1. $s_{i,s,t}$: Annual pre-tax spread over a maturity-matched Treasury for bond i, in state s in year t. Bonds are limited to GO, fixed coupon bonds without insurance or call options.

2. $B^P_{i,s,t}$: The amount of unfunded pension liabilities (liabilities - assets) in state, s, which issued bond i in year t.

3. $B^D_{i,s,t}$: The outstanding principal amount of general obligation debt in state, s, which issued bond i and at date t.

4. $T_{i,s,t}$: Time to maturity.

5. $r^f_{i,s,t}$: Maturity-matched treasury rate.

I require that a state/year combination have at least 10 valid bond observations to be included. This limits the estimation to 310 state/year combinations.[4] I have also tried alternative definitions of B^D and results are insensitive to these choices.

With that data, I perform the following non-linear least squares estimation:

$$\min_{A,B,\sigma^A_{s,t},\phi_{s,t}} \sum_{i,s,t} \left(s_{i,s,t} - \left(-\frac{1}{T_{i,s,t}} \ln \left(1 - \frac{(P^{D+P}_{i,s,t} - P^P_{i,s,t})}{(B^D_{i,s,t})e^{-r^f_{i,s,t}T_{i,s,t}}} \right) \right) \right)^2 \tag{A.93}$$

where, $V^A_{s,t} = A + B^{'}X_{s,t}$.[5] I also restrict that $\phi \in [0,1]$. This will generate one $\hat{A}, \hat{B}$ for the full sample which implicitly creates a set of 310 $\hat{V^A_{s,t}}$. Additionally I estimate 310 individual estimates for asset volatility and pension seniority: $\sigma^A_{s,t}, \phi_{s,t}$.

A.6.1 Estimation Results

First I present the coefficients from the additional structure equation for V_A in Table A.8.

The data is scaled by standard deviation to make it a bit easier to interpret and they're presented in hundreds millions of dollars. So for example a state with a one-standard-deviation higher GDP would have 271 million higher asset value. GDP, housing prices,

4. This number differs from the sample in the main body due to availability of the additional X data.

5. This is all done as a single estimation using all state/year data points simultaneously to estimate both the static sample parameters (A, B), and the state/year specific parameters ($\phi_{s,t}, \sigma_{s,t}$

Table A.8: V_A Function Estimates

GDP	HPI	Nat. Res. Rev.	Land Size	Rep. Tilt	Educ.	Tax Dif.
271.01	10.67	13.58	-113.47	9.37	-4.63	16.49

Table A.8 presents estimated coefficients from my non-linear least squares estimation for the relationship between V_A and my government value explanatory variables in Equation A.92. Data is scaled by one-standard-deviation, and coefficients are in 000s of millions of dollars.

natural resource revenue, republican tilt and tax differential all have positive relationships while land size and education are negative. Land size, education and tax differential may seem a bit counter-intuitive. Land-size may be tainted by the smaller northeastern states as compared to larger plains states. Additionally, it is possible these variables may be correlated with other variables that more obviously would have a negative effect on spreads. These estimates are pinned down primarily by the debt levels and those are going to be the correlations that matter.

Table A.9: V_A Function Estimates

	$\hat{V}_A$ (bn.)	$\hat{\sigma}_A$	$\hat{\phi}$
μ	29.75	0.27	0.65
σ	26.15	0.12	0.40
Min.	8.20	0.00	0.00
pct. 10	10.67	0.10	0.00
Median	21.57	0.27	0.88
pct. 90	48.36	0.43	1.00
Max	163.28	0.64	1.00

Table A.9 presents summary statistics of the estimates from my structural model for state government debt. There are a total of 310 state/year observations which generate each of the three parameters. The $\hat{V}_A$ for each observation is calculated based on Equation A.92 with the estimates for A and B in table A.8.

Next, I present summary statistics on other estimated parameters in Table A.9. The average asset value is about 30 billion dollars, which is about 7% of GDP, or over 1.5 times the combined debt of a state. There is also substantial variation in this estimate with a minimum value of $8 billion and a maximum of $163 billion. It is hard to have an intuitive sense for what this variable should be. The concept of a government value is not well established. On the one hand this number may seem low as it is much lower than the market capitalization than many Fortune 500 companies. On the other hand, a state government is in many ways a nonprofit as opposed to a for profit corporation. While governments have an incredible power to raise future revenue through taxes, they also have numerous expenditures for basic government functions. Moreover, they can only raise taxes so far before they find themselves losing out on revenues as citizens leave the state. As you can see the use of static A and B parameters tightens the V_A distribution as compared to the main body of the paper.

In Figure A.2 I map the cross-section of average asset values by state. The map does look intuitive. California is by far the most valuable state, with new York and Texas coming in at the top as well. Meanwhile, states like New Hampshire, Mississippi, Utah come in much smaller. This provides some evidence the estimates are at least reasonable. As discussed above, the model will estimate asset values close to the level of total government debt in order to generate non-zero spreads. As I mentioned above, the exact quantity itself may not be iron-clad, but the cross-sectional patterns line up with a priori expectations.

As for the seniority parameters, there is a mean of 0.65, but a much higher median of 0.88. Most of the estimates, 57% are corner solutions, with the higher fraction being at 1. This may seem a bit odd at first, but is not inherently shocking given that nothing in the data explicitly restricts ϕ to be between 0 and 1. One might expect a stark contrast if pension seniority is as stark as the constitutional protection variables. Again, the absolute level of these parameters is not the main goal of this exercise, but rather to think about general patterns and cross-sectional differences. For many states the coefficient is not 1 which suggests that pension liabilities may not be wholly senior to bonded debt. In Figure

Figure A.2: Mean V_A by State

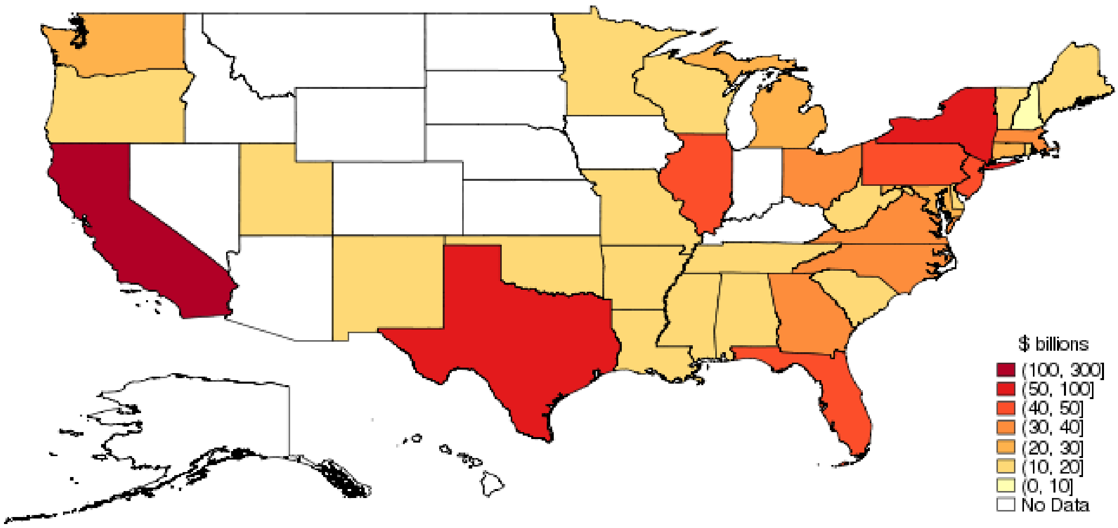

Table A.2 presents mean V_A estimates for each state. States that are blank did not have any valid V_A estimates.

A.3 I show the cross-section of median ϕ estimates by state. I look at median as opposed to mean because while the estimates are fairly stable across time for each state, it is also not uncommon to have one or two outliers out of about 15 years, which makes the means sensitive to outliers given the few number of observations. Here in the dark reds are coefficients of 1 while 0 are in the light orange. The lighter red are above 0.5 and the orange between 0 and 0.5 States like California, Louisiana, NY, NJ and CT have high coefficients. Meanwhile, Maine, Vermont, New Hampshire and Wisconsin are all around zero. Again these seem to intuitively line-up with my previous empirical proxies for seniority, which I will fully test below.

Finally, I test how the estimates for pension seniority line-up with my empirical proxies. I look at the two proxies, union membership and constitutional protections (which I break up into the two individual indicators), and run regressions of the estimated ϕ coefficients on these variables:

$$\hat{\phi_{s,t}} = \alpha + \beta Seniority_{s,t} + \epsilon_{s,t} \tag{A.94}$$

Results can be found in Table A.10.

Figure A.3: Median ϕ by State

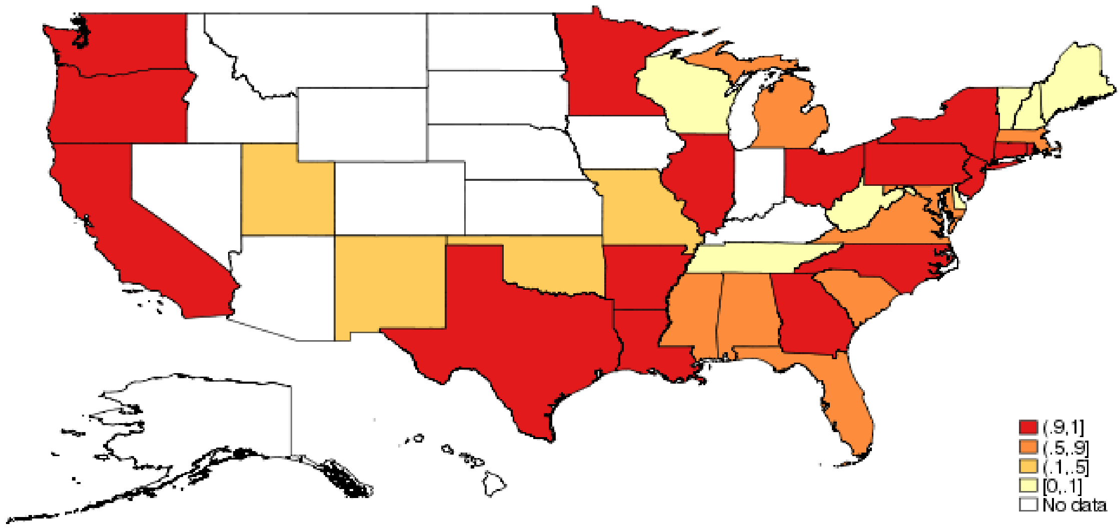

Table A.3 presents median ϕ estimates for each state. States that are blank did not have any valid ϕ estimates.

Across the board I find a positive and statistically significant relationship between the ϕ estimates and the seniority proxies. I can also run them all at the same time. If I run them all together the protected variable is no longer significant but union and explicit remain. This suggests the model is finding that cross-sectional differences in seniority implied by market prices are consistent with empirical proxies I used previously. This provides further evidence that markets are baking in assumptions about pension seniority when setting prices.

Overall my model estimates provide two major take-aways. First, there are a number of states with non-unit pension seniority. This implies there may be states where pensions are not wholly senior to bonded debt. Second there is significant cross-sectional variation in ϕ, which is consistent with my empirical proxies for pension seniority. This suggests that markets are factoring in seniority when setting bond prices, and it is consistent with various political factors which could influence recovery rates in default, through bargaining or other mechanisms.

Table A.10: ϕ Estimate and Seniority Second-Stage Regressions

Panel A: Public Union Membership	$\hat{\alpha}$	$\hat{\beta}$
Coefficient	0.5402	0.0030
t-stat	10.9801	2.4766

Panel B: Explicitly Protected State	$\hat{\alpha}$	$\hat{\beta}$
Coefficient	0.6196	0.2202
t-stat	24.9877	3.1599

Panel C: Protected State	$\hat{\alpha}$	$\hat{\beta}$
Coefficient	0.5324	0.1349
t-stat	8.7152	2.0395

Table A.10 presents results from my second-stage ϕ estimate regressions in Equation A.94. Panel A represents results using union membership as the seniority variable. Panels B and C use the Explicit and Protected constitutional variables respectively.