The Revenue Demands of Public Employee Pension Promises*

Robert Novy-Marx
University of Rochester and NBER

Joshua D. Rauh
Kellogg School of Management and NBER

June 2011

Abstract

We calculate the increases in state and local revenues required to achieve full funding of state and local pension systems in the U.S. over the next 30 years. Without policy changes, contributions to these systems would have to immediately increase by a factor of 2.5, reaching 14.2% of the total own-revenue generated by state and local governments (taxes, fees and charges). This represents a tax increase of $1,398 per U.S. household per year, above and beyond revenue generated by expected economic growth. In thirteen states the necessary increases are more than $1,500 per household per year, and in five states they are more than $2,000 per household per year. Shifting all new employees onto defined contribution plans and Social Security still leaves required increases at an average of $1,223 per household. Even with a hard freeze of all benefits at today's levels, contributions still have to rise by more than $800 per U.S. household to achieve full funding in 30 years. Accounting for endogenous shifts in the tax base in response to tax increases or spending cuts increases the dispersion in required incremental contributions among states.

* Novy-Marx: (585) 275-3914, Robert.Novy-Marx@simon.rochester.edu. Rauh: (847) 491-4462, joshua-rauh@kellogg.northwestern.edu. Rauh gratefully acknowledges funding from the Zell Center for Risk Research at the Kellogg School of Management. We thank David Wilcox for discussion, as well as seminar participants at the Wharton Household Finance Conference, the Harvard University Public Finance Seminar, HEC Paris, and the University of Lugano for helpful comments and suggestions.

The condition of state and local government defined benefit (DB) pension systems in the U.S. has received national attention in debates over government budgets. The academic literature considering this issue has primarily focused on three main questions. First, analyses of the strength of the legal claims of public pension beneficiaries have informed studies of the measurement of liabilities under appropriate discount rates (see Gold (2002), Novy-Marx and Rauh (2008, 2009, 2011a, 2011b), Brown and Wilcox (2009)). Second, a number of papers have considered the optimal level of funding for public employee pension plans (D'Arcy et al (1999), Bohn (2011)) in light of the political economy of public sector debt decisions (Persson and Tabellini (2000), Alesina and Perotti, (1995)). Third, an extensive literature has considered the question of optimal asset allocation (Black (1989), Bodie (1990), Lucas and Zeldes (2006, 2009)), Pennacchi and Rastad (2011)).[1]

Missing in the discussion has been an analysis of the revenue demands of the pension promises to public employees. If states and local governments are going to pay pensions under current policies, how much more revenue will need to be devoted to these systems? This paper attempts to fill that gap. It provides calculations of the increases in contributions that would be required to achieve fully funded pension systems. These contribution increases are calculated relative to a base of Gross State Product (GSP) growth applied to today's contributions. Results are presented under a variety of possible assumptions about the level and cross-sectional variation of growth rates of state and local governments, the treatment of future work by current employees, and the sensitivity of state and local GSP growth to policy changes. We loosely call the latter effects "Tiebout effects" after Tiebout (1956).[2]

Contributions from state and local governments to pay for public employee retirement benefits, including the employer share of payments into Social Security, currently amount to 5.7% of the total own-revenue generated by these entities (all state and local taxes, fees, and charges). In aggregate, and assuming each state grows at its 10 year average with no Tiebout effects, government contributions to state and local pension systems must rise to 14.2% of own-revenue to achieve fully funded systems in 30 years. Average contributions would have to rise to

[1] Other papers have surveyed various labor market, behavioral, and political economy aspects of public pensions (Friedberg (2011), Beshears et al (2011), and Schieber (2011)). Shoag (2011) considers macroeconomic impacts of pension contributions. Fitzpatrick (2011) measures the valuation placed by a group of Illinois public employees on their pension benefits based on their choices to buy into additional retirement benefits.

[2] To be precise, the effect we consider is limited to taxpayers' "voting with their feet," not the equilibrium provision of local public goods.

40.7% of payroll to achieve these goals, corresponding to an increase of 24.3% of payroll. This analysis starts from our estimates of December 2010 asset and liability levels for state and local pension funds, and holds employee contributions as a percent of payroll at their current rates.

These results may be best understood in terms of per-household contribution increases that would have to start immediately and grow along with state economies. The average immediate increase is $1,398 per household per year. In thirteen states, the necessary immediate increase is more than $1,500 per household per year, and in five states they are more than $2,000 per household per year.

Introducing Tiebout effects, we examine how the results change when raising revenues or cutting services reduces a state's long-run economic growth rates, as taxpayers respond by relocating to locations that provide more attractive services at lower prices. This has essentially no effect on nationwide totals and means, but increases the dispersion in needed revenues among states. States whose governments require the largest increases relative to GSP, such as New Jersey, Ohio, and Oregon, would need the immediate increase to be several hundred dollars larger per household under a sensitivity parameter of two (two percentage point reduction in long-run GSP growth per percentage point of GSP raised in revenues), whereas states whose governments require the smallest increases see their required increases decline. The effects grow as the sensitivity parameter increases.

Measuring the revenue demands of public pension systems under current policy requires calculating "service costs" for the workers in the plans. These quantify the present value of newly accrued benefits, i.e., the cost of the increase in pension benefits plan participants earn by working one more year. State and local systems follow GASB rules and discount the pension liabilities using expected returns on assets. Using Treasury inflation-linked yield curves to measure the present value of deflated benefit promises, we find that with the possible exception of Indiana, there is no state for which the current total contributions by all state and local government entities are greater than the present value of newly accrued benefits for those entities. At least thirteen states would need to double contributions just to pay this service cost.

The paper then examines how much the required contribution increases would be reduced under several policy changes that reduce future benefit accruals. To start, we perform the analysis assuming that all new hires receive defined contribution (DC) plans, as has happened in

Utah and Alaska and been proposed in Florida.[3] We assume that the DC plan will cost the employer 10% of payroll. Assigning new hires to DC plans is known as a "soft freeze" of the DB plan. We also assume that new workers in plans whose workers are currently excluded from Social Security (representing around 30% of today's public employees) would have to be enrolled in Social Security, with the cost (12.4% of payroll) borne entirely by the employer.

Our analysis shows that soft freezes have moderate revenue-saving effects. The required increases decline from $1,398 to $1,223 per household (excluding Tiebout effects). By making the employer responsible for DC contributions of 10% of payroll plus the entire 12.4% Social Security contribution, these calculations by assumption make the soft freeze relatively expensive for systems where employees are not in Social Security. As a result, soft freezes under the above parameters reduce the fiscal burden for all but seven of the states that have not already closed DB plans to new workers. The exceptions are states that have relatively high employee contribution rates with low Social Security coverage: Ohio, Colorado, Illinois, Massachusetts, Missouri, Louisiana and Maine. For those states, moving to a cost structure where the governments bear the costs of paying 10% of payroll into a DC plus the entire 12.4% Social Security contribution would be more costly than actually funding the DB promises for new workers. Such an analysis necessarily does not reflect one major advantage of DC plans, namely that their transparency ensures there will be no unfunded liabilities or unrecognized public sector borrowing through pension promises.

An alternative policy that has not, to our knowledge, yet been implemented by any public DB system but that is not uncommon in the private sector, is a "hard freeze." Under a hard freeze all future benefit accruals are stopped, even for existing workers. No earned benefits (including cost of living adjustments) are revoked, but benefits cease to grow with service and salary. We assume that retirement benefits for all future work under a hard freeze would be compensated with a DC plan with the same parameters and cost sharing as in our "soft freeze" scenario, including Social Security for those employees currently excluded from the system. Hard freezes have more significant revenue-saving effects. If all plans were hard-frozen, total increases would average only 4.9% of own-revenue, or $805 per household. This analysis assumes that public employees would accept DC plans with a 10% employer contribution (which is relatively

[3] In the baseline analysis under no policy changes, we have incorporated the fact that soft freezes are already effective in Utah and Alaska.

generous by private sector standards) without compensating salary increases, with the employer picking up the full cost of any Social Security enrollment.

This paper has a number of implications for household finance. First, over the next several decades, U.S. households face the prospect of substantial increases in tax burdens at the state and local level, likely combined with cuts in public services, particularly in the states that have the largest unfunded liabilities. Second, states that will not have to devote much additional revenue to this problem may in fact benefit. Taxpayers may leave the states that are the most burdened by the legacy liabilities and look for places with lower taxes and better public services. This sorting is likely to further increase the burden on states with the largest unfunded liabilities. Third, in states where the burden is large relative to revenue, there is likely an increased danger of a municipal debt crisis if the holders of public debt lose confidence in the ability or willingness of taxpayers in the state to foot the bill for legacy liabilities.

This paper proceeds as follows. In Section I we explain the institutional background behind public sector DB plans in the U.S. In Section II we describe the data and the aggregation of the systems to the state and local level, and sketch out current revenue and pension contribution policy. In Section III, the model for making these calculations is presented in detail. In Section IV we present and discuss the results. Section V concludes.

I. Institutional Background

Most U.S. state and local governments offer their employees DB pension plans. This arrangement contrasts with the defined contribution (DC) plans that now prevail outside the public sector, such as 401(k) or 403(b) plans, in which employees save for their own retirement and manage their own investments. In a DB plan the employer promises the employee an annual payment that begins when the employee retires, where the annual payment depends on the employee's age, tenure, and late-career salary. For a sample of the large public finance literature on the costs and benefits of DB and DC plans, see Bodie, Marcus, and Merton (1988), Samwick and Skinner (2004), and Poterba et al (2007).

When a government promises a future payment to a worker, it creates a financial liability for its taxpayers. When the worker retires, the state must make the benefit payments. To prepare for this, states typically contribute to and manage their own pension funds, pools of money dedicated to providing retirement benefits to state employees. If these pools do not have sufficient funds when the worker retires, then the states will have to raise taxes or cut spending at that time, or default on their obligations to retired employees. When governments promise deferred compensation in the form of DB pensions to employees when they retire, but do not set aside sufficient funds to honor those promises, they are effectively borrowing from future taxpayers. As a result, the definition of “sufficient funds” is important.

Government accounting procedures in this area contrast with the financial dictum that cash flows should be discounted at discount rates that reflect their risk. Under guidelines established by the Government Accounting Standards Board (GASB) state and local governments discount their pension liabilities at *expected returns on their plan assets*. Plans' actuarially recognized liabilities are consequently mechanically decreasing in the riskiness of the plans' investments. Plan actuaries typically assume that the expected return on their portfolios will be about 8 percent, and then measure the adequacy of assets to meet liabilities based on that expected return. This accounting standard sets up a false equivalence between relatively certain pension payments and the much less certain outcome of a risky investment portfolio (see Gold (2002) and Bader and Gold (2004)).

As Brown and Wilcox (2009) point out, DB pension promises based on current levels of service and salary are extremely likely to be met.[4] In general, if state and local governments tell public employees that their benefits will be paid no matter how the assets in the fund perform, then liability measurement should reflect that promise. Novy-Marx and Rauh (2008, 2009, 2011a, 2011b) discount pension liabilities at rates that reflect their relatively low levels of risk, arguing primarily for the use of the Treasury yield curve to discount nominal payments. They focus on the accrual measure called the Accumulated Benefit Obligation (ABO), which essentially equals the present value of what would be owed if the plan were frozen and workers did not earn the rights to any benefits beyond what they would be entitled to based on today’s service and salary. Other possible measures of obligations take into account some of the increase in benefits expected with future service.

In this paper we are relying on similar procedures to Novy-Marx and Rauh (2011a) in determining the cash flow benefit payments that states will have to make. One difference is in

[4] A number of states enshrine the payment of pensions as an obligation within their constitutions, providing explicit guarantees that public pension liabilities will be met in full. Furthermore, state employees are a powerful constituency, making it hard to imagine that their already-promised benefits would be impaired. Indeed, Brown and Wilcox (2009) discuss that in major municipal debt crises of the past, bonds were restructured while pension debt was honored in full. Some examples of this are Orange County in the 1990s, and the bankrupt city of Vallejo, California currently. Another consideration is whether the federal government would bail out any state that threatened not to pay already promised pensions to state workers.

the treatment of inflation. We consider real cash flows, deflating nominal cash flows forecast along the lines of Novy-Marx and Rauh (2011a, 2011b) using the inflation assumption built into the forecast nominal benefit payments.[5] Accordingly, we assume that the real value of assets grows at the point on the TIPS yield curve that corresponds to the average duration of real liabilities (21 years), which is 1.7%. This assumption implies that the nominal value of assets grows at inflation plus 1.7%.

A second difference is that the exercise in this paper requires an explicit calculation of the annual economic cost of the retirement benefits earned by workers. In the baseline scenario without pension freezes or policy changes, this cost is the annual present value of new benefit promises, otherwise known as the service cost. Again, we use real Treasury yields (based on TIPS) to discount deflated cash flows, rather than nominal Treasury yields to discount nominal cash flows, to calculate the change in the present value ABO liability resulting from an additional year of work. In the baseline scenario with no policy changes, we calculate the contributions necessary to pay off any unfunded ABO liability that exists today over 30 years, plus the present value of all new benefit accruals over that time period.

A third difference is that we are explicitly accounting for the costs of new workers. In the baseline scenario, the annual cost of a new worker is that worker's service cost. To model a soft freeze, or closing of the plan to new workers, the pension cost of new employees is assumed to be that of a DC plan with an employer contribution equal to 10% of payroll, plus the full cost of providing Social Security to new workers in those systems that do not currently enroll workers in Social Security. The cost of Social Security is 12.4% of payroll, which generally is split equally between employers and employees, but our analysis is based on the notion that workers not in Social Security would require pay increases of 6.2% to pay their share, so that the cost of both the employer and employee share would effectively be paid by the employer.

Our soft freeze analysis is performed independent of any calculation of service costs. It is convenient to calculate the contributions necessary to pay off the Present Value of Benefits (PVB) liability, which forecasts all future accruals for current workers, as opposed to the ABO. In other words, this calculation solves for the government contribution rates over the next 30 years that will be necessary, in conjunction with the plans assets and investment return (inflation

[5] This is in fact a slightly more conservative assumption, because states' inflation assumptions, which are used to forecast their future nominal liabilities, are on average slightly higher than the inflation assumptions currently built into the nominal yield curve.

plus the current real yield), to just pay all expected benefits, taking into account both employee contributions and the costs of paying DC benefits for new employees.[6]

We also consider the possibility of hard freezes, in which all benefit accruals are stopped, including for current workers. In a hard freeze no accumulated benefits are taken away, but employees stop accruing defined benefits with additional years of service and salary increases. Instead, each employee receives a DC account (in the case of corporations this is generally a 401(k) plan) and all contributions from the date of the freeze go into that account. Major corporations that have undertaken freezes include Verizon Communications, IBM, and Alcoa. In our modeling of a hard freeze, we assume that the governments need only pay off today's unfunded ABO liability over 30 years, with DC contributions for everyone going forward and the complete loss of future employee contributions to DB plans.[7]

II. Data on Pension Systems at the State and Local Level

This section describes the data sources used in this study. Our ultimate analysis, given the potential fluidity of whether state or local governments are responsible for unfunded liabilities, aggregates all state and local pension systems within each state. Similarly, we aggregate revenue sources from the level of state governments and local governments to the state level. A key element of the descriptions in this section is therefore how the state and local government data are aggregated to the state level.

A. Data on Defined Benefit Pension Systems

Key ingredients in the calculations include all of the inputs that go into the cash flow calculations in Novy-Marx and Rauh (2011a, 2011b), as well as data on pension fund assets from those same sources. The primary dataset consists of information from Comprehensive Annual Financial Reports (CAFRs) of 116 pension systems at the state level used in Novy-Marx and Rauh (2011a), and information from the 77 local-system CAFRs used in Novy-Marx and Rauh (2011b), for a total of 193 pension plan systems. The sample plans consist of the universe of plans with more than $1 billion in assets. The critical inputs to the model from these reports are: the system's own reported liability, the discount rate used by the system, the accrual method

[6] We also account for contributions that current workers make to the DB plans after the amortization period, but these have essentially no impact on the results as very few current employees will still be working for the plans in 30 years. See section III for further details.

[7] Our analysis of pension freezes thus relates to a small academic literature on the effects of freezes on costs or firm value, including Comprix and Muller (2010), Milevsky and Song (2010), and Rauh and Stefanescu (2009).

employed by the system, the average and total salary of active workers, the ratio of workers who are separated and vested but not yet retired to those who are retired and drawing a benefit, the benefit factors in the benefit formulas, the actual benefit payouts in 2009, the cost of living adjustments, and the assumed inflation rates. These variables are all summarized in Novy-Marx and Rauh (2011a, 2011b).

We explain the methodology for estimating the cash flows on a plan-by-plan basis in Section III. The study provides estimates for the universe of state and local defined benefit plans by scaling up the cash flows from the state and local plans that we have to match the benefit payouts from the U.S. Census Bureau (2010a) at the level of each state. The Census Bureau provides measures of benefit payments at an aggregated level to all state and local government employees within each state. The scaling factor used is simply the ratio of total benefits of in-state public pension systems provided by the Census to benefits of in-state plans in our CAFR-based sample. The implicit assumption is that the trajectory of future cash flows of local plans that are not covered in our local-system sample are similar to those of the state and local plans for which CAFRs were obtained. The average adjustment across the 50 states is 6.7% and the median is 3.5%. The largest adjustment factors were for Nebraska (56.9%), Louisiana (35.6%), and Michigan (30.9%). The Census of Governments lists substantial numbers of small local plans in those states that are not captured in our sample of local reports.

To calculate pension assets at the state level, a similar procedure was followed. We aggregate all state and local plan assets as of June 2009 to the state level. We apply the adjustment factors above, which again are based on ratios of benefits for covered versus not-covered plans. Finally, we increase plan asset to reflect the higher levels of assets in 2010 than in 2009. We use an adjustment factor of 1.235, based on the 23.5% increases over this 18 month period documented in the Federal Reserve Flow of Funds.

To bring estimated liabilities to December 2010, we calculate from the CAFR database that stated liabilities grew at a 5.52% annual rate between plan years 2007 and 2008, and at a 5.51% annual rate between plan years 2008 and 2009.[8] Given the stability of this growth rate, we applied a 5.5% annualized growth rate to liabilities between June 2009 and December 2010, in

[8] Casual observation of actuarial reports suggests that some of the liability growth was predicted by state and local actuarial models, but some is from the "actuarial loss" of realized outcomes on job separation and mortality being out of line with predicted values.

order to predict the value of what stated liabilities under the systems' own accounting methods would be if they were disclosed as of December 2010.

Our calculations also require knowing which systems include their workers in Social Security. For this purpose, we begin with data from the Center for Retirement Research (2011) and augment it with searches of the systems' own websites. Of the state-level plans in our sample we find that 16% of plans do not participate in Social Security, representing 24% of total payroll. At the local level, there is less Social Security coverage. Around 36% of locally sponsored plans in the sample had no Social Security coverage, due in large part to the fact that many systems for public safety officials do not participate. Around 52% of the locally sponsored plans have all participants in Social Security. In the remaining 12% of the local plans, some group (usually public safety officials) were excluded from Social Security whereas the rest of the employees were in Social Security.[9]

B. Contributions to Pension Systems

The study requires measures of contributions to state and local pension systems from both employees and governments. U.S. Census Bureau (2010a) contains data on total pension contributions to plans at each level of government, decomposed into government contributions and employee contributions, for 2008. Using calculations on contribution growth rates from Novy-Marx and Rauh (2011a), we estimate 2009 contributions based on the growth rate of employee and government contributions in the state plans covered by that study. When looking at contribution measures in systems that include Social Security, we add 6.2% of payroll to employer (and employee) contributions. The Technical Appendix provides further details.

C. State and Local Revenues, Debt, and Payrolls

The study also requires data on a number of revenue and spending figures at the state and local level. These variables are primarily used as scaling variables in our analysis, although historical growth in GSP is used in some of the scenarios to project future state-level income growth. Payroll of employees in the plans comes from the CAFRs themselves, with the scaling factors described above applied so as to capture workers in plans that our samples do not cover.

[9] Specifically, out of the 77 local plans, we located Social Security information for 67 of them. Of these, 35 had full participation, 8 had some employees exempted, and 24 did not participate in Social Security at all. Of the 8 that had some employees exempted, we assumed 80% of employees were covered, based on rough averages in the plans for which we could obtain precise information. For the 10 plans for which information was not available, we assumed coverage at the average level over all 77 local plans.

Revenue data from the U.S. Census Bureau (2010b) are collected separately for the state and local level and then aggregated to the state level, so that the government revenues for a given state again reflect the aggregate of the state government and all local government entities within the state.[10]

We focus on two revenue measures. First, we consider a broad measure called Total Own Revenue that includes all revenue except (i) the "insurance trust" revenues reflecting the returns of pension funds themselves; and (ii) intergovernmental revenues, which are primarily transfers from the federal government but also transfers from state governments to local governments and vice-versa. The need to exclude transfers between state governments and local governments is obvious, as otherwise revenues would be double counted. We exclude federal transfers as the point of the exercise is to examine how much state and local revenues will have to grow to pay pensions in the absence of an expansion of federal assistance.

Second, we examine Tax Revenues alone. These exclude fees and charges, most of which are for services rendered. The idea here is to consider how state and local governments could pay for unfunded pensions through traditional taxation sources like income taxes, sales taxes, and property taxes. Compared to Total Own Revenue, scaling by Tax Revenues assumes that states will not raise fees for services such as university tuition to pay for unfunded pension liabilities.

The U.S. Census Bureau (2010b) also contains data on debt outstanding at the state and local level, using a definition that excludes unfunded pension liabilities. As with revenues, debt information is collected separately for the state and local level and then aggregated to the state level, so that the government debt measures for a given state in our study again reflect the aggregate of the state government and all local government entities within the state.[11]

D. GSP and Population

Gross state product is from the Bureau of Economic Analysis (2010). We examine a 10-year history of gross state product growth by state for the baseline scenario in which the future growth rate for a state is assumed to be the 10-year historical average growth rate for the state. Population estimates are from the U.S. Census Bureau for the year 2009. To calculate the

[10] Revenues at the state level are available for 2009. Local-level revenues are only available for 2008, so we assume that the 2009 ratio of local to state revenues remains the same as the 2008 ratio for each state.
[11] As with revenues, the state-government information is available for 2009 whereas the local-government information is only available for 2008. In estimating total state and local debt aggregated at the state level, we therefore assume that the 2009 ratio of local to state debt remains the same as the 2008 ratio for each state.

number of households we use the estimate from the latest decennial census of 2.59 individuals per household.[12]

E. Summary Statistics

Table 1 shows summary statistics. The level of observation is the state. The table begins with the levels of the key revenue and income variables. Total tax revenue was $1.2 trillion in 2009, and total own revenue was $1.9 trillion in 2009. Note that this includes revenues from both the state and local levels of government. Total GSP was $14.1 trillion, and there were 117.8 million households.

The rest of Table 1 shows payroll, government contributions to DB pension plans, and employee contributions to DB pension plans, scaled by each base variable: tax revenue, total own revenue, GSP, and number of households. Total government payroll was $678 billion in 2009, amounting to 55.8% of tax revenue, 34.8% of total own revenue, 4.8% of GSP, and $5,757 per household. There is dispersion in these quantities. For example, Nebraska spends only 2.9% of GSP on state and local payroll, while New Mexico spends 6.2% on state and local payroll.

Government contributions are shown two ways: first including the employer's share of Social Security (6.2% of payroll) in systems that participate in Social Security, and then excluding the employer's share of Social Security. In states where no public workers covered by DB pension plans participate in Social Security, the contributions including Social Security and excluding Social Security are the same.

Total government contributions including Social Security contributions amounted to $110.9 billion, and excluding Social Security contributions were $80.7 billion. The Social Security contributions comprise 4.5% of aggregate payroll, suggesting a Social Security coverage ratio of around 73% of payroll. Equally weighted across the 50 states, total government contributions average 16.4% of payroll, 9.1% of tax revenue, 5.7% of total own revenue, and 0.8% of GSP. The average per household government contribution to DB pension systems plus Social Security at the state level is $941. Excluding Social Security, the government contributions are lower on average by 2.5% (= 9.1% - 6.6%) of tax revenue and by 1.6% (= 5.7% - 4.1%) of total own revenue, and average to $684 per household.

[12] See http://quickfacts.census.gov/qfd/states/00000.html .

Similar to the treatment of total government contributions, total employee contributions are shown two ways in Table 1: first including the employee's share of Social Security (6.2% of payroll) in systems that participate in Social Security, and then excluding that share. Across the 50 states, total employee contributions average 10.2% of payroll, 5.7% of tax revenue, 3.5% of total own revenue, and 0.5% of GSP.

Table 2 shows levels of contributions, payroll, and revenues for state and local systems, aggregated to the state level. The table is in descending order of per-household government contributions to DB plans, including Social Security. Colorado, whose workers do not participate in Social Security, contributed only 2.8% of total own revenue towards public employee pensions in 2009, the lowest value across the states, while Rhode Island contributed 9.3% (including to Social Security), the highest value. Colorado also contributed the lowest per household amount of $463, whereas New York contributed $1,739, the highest per-household amount. Excluding Social Security, North Carolina contributed the lowest per-household amount at $173 per household, while New York contributed $1,291 (as shown in Table 1).

Government contributions to DB systems are not mandated by any federal rules. GASB standards specify how state and local governments are to calculate service costs, or the present value of newly accrued benefits. These standards further guide state and local governments in calculating an Actuarially Required Contribution (ARC), which consists of paying the present value of newly accrued benefits plus a portion of the unfunded liability each year.

Not all governments contribute the ARC. Approximately 45% of state government systems in our sample paid less than the full ARC in 2009, 40% paid less than 90% of the ARC, and 25% paid less than 80%. Some systems paid very little, as reflected by the fact that the mean system that did not pay the full ARC paid only 73% of the ARC. Furthermore, the part of the ARC that represents the cost of new service (as well as the unfunded liability) is itself calculated using the expected return discounting methodology and therefore understates the true economic cost of new benefits. As a starting point for our analysis, we will consider what the true present value of newly accrued annual benefits is as a percentage of payroll.

III. Methodology

This section explains the methodology employed to determine benefit payments, calculate new service costs, and evaluate the contribution increases necessary to payoff states' unfunded pension obligations.

A. Forecasting Benefit Payments

A starting point for our analysis is the stream of cash flows that each system will pay out to beneficiaries. There are two fundamental challenges. First, the governments themselves do not disclose the series of cash flows that they have discounted. They disclose a present value of liabilities, a discount rate, and actuarial assumptions. As a result, the streams of cash flows must be reverse-engineered on the basis of the information provided.

Second, different calculations require cash flows related to liabilities that reflect service and salary as of different points in time. For example, as explained in Section I, in the baseline scenario with no policy changes we calculate the contributions necessary to pay off any unfunded ABO liability that exists today over 30 years, plus the present value of all new ABO benefit accruals over that time period. The ABO is often referred to as the "termination liability," because it recognizes only the portion of expected future pension benefits payments due to an employee's current wages and service. In the soft-freeze calculations, however, the most convenient formulation calculates the contributions necessary to pay off a broader liability concept, the PVB, which forecasts all future accruals for current workers including projections of estimated future service and salary growth.

The exercise of separately estimating ABO and PVB cash flows is further complicated by the fact that the actuarial liability employed by most systems is calculated from neither the ABO cash flows nor the PVB cash flows but rather (in the grand majority of cases) from a concept called Entry Age Normal (EAN). The EAN recognizes future liabilities in proportion to the ratio of the present value of a worker's wages earned to date and the present value of lifetime wages, which leads to service accruals that are a constant fraction of an employee's wages throughout the employee's career. In addition to presenting our baseline analysis under ABO benefit recognition, we also present alternative calculations using the EAN method of benefit recognition and demonstrate that the required tax increases are quite similar.[13]

Future payments to plan participants are estimated from the procedure detailed precisely in the Technical Appendix. Here we describe the calculations in general terms. This is the same methodology as that employed in Novy-Marx and Rauh (2011a, 2011b) with two notable differences. First, the model is calibrated to match not only the expected first year payout to

[13] This similarity is not surprising since for a career worker the accrued cash flows under all the methods (ABO, EAN, and PVB) converge at retirement. Under EAN accounting, today's unfunded liability is larger than under ABO accounting, but benefit accruals going forward are smaller.

beneficiaries and the stated liability, but also the total wages of each plans' current active workers. Second, because we are interested in the plans' future *real* liabilities, we forecast real liability cash flows using the uniform inflation assumption of 2% per year, adjusting COLAs and wage growth assumptions appropriately to reflect the differences between this rate and the plans' stated inflation rate assumptions, for reasons discussed below.

There are three groups of plan members that must be considered: current employees, retirees, and separated vested workers (individuals that are no longer in public employment, are not currently receiving pension benefits, but are entitled to take them at some point in the future).

For each plan, we first forecast the nominal pension payouts to current employees recognized under the plan's own stated accounting method. We assume active workers' age and service distributions, as well as the average wages of employees at each level of age and service relative to the overall plan average wage, are consistent with their averages from a sample of CAFRs of the states with the largest total liabilities.[14] Total wages of active workers are taken directly from the plans' CAFRs. For each age and service level we assume workers are split evenly by gender, and forecast the expected number retiring at each year in the future, and their salaries at the time they retire, using assumptions on wage growth and separation probabilities by age derived from the same CAFRs used to calculate the age-service matrix.

Based on common practice and the observed age distribution of retirees, we assume that retirees are eligible for full benefits at age 60, but can start taking benefits as early as 55 by taking a linear 6% benefit reduction for each year they start taking benefits before age 60, consistent with common practice in state public pension systems.

This schedule, together with the fact that COLAs only apply after retirement, make early retirement more than actuarially fair to plan participants, so we assume that workers retiring younger than 55 will begin taking benefits at age 55, while workers retiring older than that will begin taking benefits immediately. For each retiring worker we calculate initial benefit payments using the worker's service and salary at the time of separation and the plan-specific retirement benefit factor. Expected nominal cash flows at each year in the future are then forecast using plan-specific COLAs and the RP-2000 mortality tables (combined employee/retired healthy), assuming that 60 percent of participants are married at the time they retire to a spouse of the same age and that plans allow for 50 percent survivor benefits.

[14] See the Internet Appendix Table II.C. in Novy-Marx and Rauh (2011a) for the precise age-service matrix.

For retired workers we assume a distribution of retiree ages, and for each age an average annuity benefit relative to the overall average plan annuity benefit, derived from CAFRs for which this information is available. Total benefits paid are taken directly from the CAFR of each plan. We then forecast nominal cash flows at each year in the future, again using plan-specific COLAs, and the RP-2000 mortality tables assuming that 60 percent of participants are married at the time they retire to a spouse of the same age and 50 percent survivor benefits.

The number of vested, separated members not yet receiving benefits is taken directly from CAFRs. Vesting typically requires five years of service, and workers rarely leave public employment with more than 15 years of service without retiring and taking benefits. We consequently assume that these members have between 6 and 15 years of service (each level equally likely), and that the age distribution at each service level is the same as that for currently employed workers with the same level of service. We assume a participant's benefits eligible salary is equal to the current average salary across plans of active workers with the same age and service. We then adjust this to reflect the experience of current retirees, by assuming that separated workers in plans in which current retirees receive large benefit payments relative to those in other plans will also receive similarly larger benefits when they retire. We assume separated workers will begin taking benefit payments at age 55, initially equal to 70% of their benefits eligible salary times their service times the plan-specific benefit factor. This 70% reflects the impact of taking payments five years before the age of full retirement under the linear 6% per year adjustment schedule. We then forecast cash flows at each year in the future using our standard methodology, employing plan-specific COLAs and the RP-2000 mortality tables with a 60 percent married rate and 50 percent survivor benefits.

In the final step of estimating the nominal cash flows, we calibrate our model to plans' stated liability by multiplying each series by a geometric sequence that starts at one, such that the total model generated cash flows recognized under the accounting methodology employed by the plan yields the plan's stated liability when discounted at the plan-chosen discount rate. This procedure uses the information contained in the plan level variation in stated liabilities to proxy for unobserved state level variation in other variables (e.g., the age-service distribution), without altering either the total salaries of the plan's current workers or the first year benefits payments to a plan's current annuitants. The average rate at which this geometric sequence grows is -

0.35% for state plans and -1.48% for local plans, with standard deviations of 1.63% and 1.56%, respectively.

These cash flows are then calculated under each of four different accrual concepts: the three described previously (ABO, EAN, and PVB), as well as one other concept used in the reports of some plans called the Projected Benefit Obligation (PBO), which accounts for future expected wage increases but not future service.[15] Note that this adjustment only affects the cash flows related to the currently active workers.

The procedure up to this point yields a stream of nominal cash flows, very similar to the ones which Novy-Marx and Rauh (2011a, 2011b) discount at nominal rates. For most of our calculations in this paper, however, we require cash flows in real terms. One way this could be done would be to deflate the cash flows using the states' own inflation assumptions. Doing so would, however, understate the true liability represented by participants not yet receiving benefit payments. This is because these participants' liabilities have a nominal component that is undervalued using the states' inflation rate assumptions, which are higher than consensus estimates or those implied by the bond markets. Benefit payments essentially represent a real liability once they start getting paid, because of the COLAs, but COLAs typically do not apply until a participant starts taking benefits. High assumed inflation rates consequently excessively deflate the liabilities of those participants that are separated and vested but not yet receiving benefits, as well as those of any workers that will retire before the age at which they can first start taking benefits.

When calculating the real liability cash flows we consequently use a uniform inflation assumption of 2% per year across plans, taken from the Federal Reserve Bank of Cleveland's estimates of inflation expectations.[16] When doing so we adjust COLAs downward by the difference in a plan's own inflation rate assumption and the uniform 2% assumption. We also reduce the wage growth by age assumptions to reflect the lower assumed rate of inflation, reducing assumed wage growth by the difference between the average inflation assumption across plans and 2%. This results in a new set of forecast nominal liability payment streams for

[15] In state and local government reports the PBO is generally referred to as a Projected Unit Credit (PUC) method. Under FASB accounting, firms calculate PBO liabilities and report unfunded PBO liabilities on their balance sheets.

[16] The estimates, as well as the methodology employed to calculate them, can be found at http://www.clevelandfed.org/research/data/inflation_expectations/index.cfm?DCS.nav=Local.

each plan. These are then deflated using the 2% per year inflation assumption, yielding each plan's forecast real benefit payments.

As a final step, the resultant calibrated real liability streams are aggregated to the state level using the methodology explained in Section II. The scaling factor used for each state is simply the ratio of total benefits of in-state public pension systems provided by the Census to benefits of in-state plans in our CAFR-based sample. The implicit assumption is that the cash flows of local plans that are not covered in our local-system sample are similar to those of the state and local plans for which CAFRs were obtained. The average adjustment across the 50 states is 6.7% and the median is 3.5%.

B. Calculating New Service Costs

The annual cost of a worker's new service accrual is the difference in the present value of expected future benefit payments calculated using the worker's current age, wages and service, and those calculated using the worker's age, wages and service from the previous year. We calculate the state-level service costs under both the ABO and EAN, which, as explained in Section A above, recognize future benefit payments differently. We also calculate the present values of the increases in the recognized expected liability payments both 1.) using states own assumed discount rates, and; 2.) by deflating nominal cash flows at the inflation rate and discounting the resulting real cash flow stream using the December 2010 zero-coupon TIPS yield curve.

When calculating the service costs using states' own discount rate assumptions we forecast nominal liability payments using the states' own inflation assumptions and discount using the state-chosen nominal discount rates. However, for the reasons explained in Section A, when calculating the real liability cash flows we use a uniform inflation assumption of 2% per year across plans, taken from the Federal Reserve Bank of Cleveland's estimates of inflation expectations. We discount these real cash flow streams using the December 2010 zero-coupon TIPS yield curve.

For the actual service cost calculation, we begin with the calculation of the stream of benefit payments (under the relevant actuarial method, i.e. ABO or EAN) to all current workers not retiring over the coming year. Because we exclude retiring workers, these forecasts do not include any payments in the following year. We then forecast the expected benefit payments to all workers one year later. We use two different methodologies for forecasting continuing workers' wages. We either assume that they grow in accordance with our model's assumptions regarding wage growth with age, or that they are consistent with the salaries of workers one year older and with one year more service from the preceding year, adjusted upward to reflect inflation. The two methodologies yield almost identical results, and the numbers we present in the tables that address this question (particularly Table 3) are averages of the two.

Finally, plan service costs are aggregated to the state level, and adjusted to reflect plans not covered in our CAFR database, using the same procedure described in Section II, and reviewed at the end of section A above.

C. Amortizing Legacy Liabilities While Keeping Current DB Plans

This section explains how we calculate the rate, relative to wages or GSP, at which states and localities need to contribute for the next 30 years to completely amortize the unfunded pension liability, measured under either the ABO or EAN. After the 30-year amortization period the contribution rate is assumed to drop to the level required to fund new service accruals.

Each year plan assets are assumed to grow at a real rate of 1.71%, the 21 year zero-coupon TIPS yield, where this maturity is picked to match the duration of the real pension liabilities at the corresponding yield. This is the real rate that may safely be achieved when assets are picked to match liabilities, and is equivalent to assuming that assets will grow at inflation plus 1.71%. Assets are then reduced by the benefit payments made that year, to reflect outflows to plan participants.

To these assets we add the contributions from plan participants, which are assumed to be a constant fraction of wages. For each state the contribution rate for plan participants is taken from the data, and averages just under 6%, though there is a great deal of variation across states. In Oregon plan participants make essentially no contributions to the DB plan, while in Massachusetts the employee contribution rate exceeds 10%. Plan participants' aggregate salaries are taken from the model, and account for mortality, retirement, and wage growth.

Finally, we add the contributions from employers, less the cost of new service accruals. State and local governments are assumed to contribute a constant fraction of total adjusted payrolls for the next thirty years, the "amortization rate." Total payrolls, as well as GSPs, are assumed to grow at a constant real rate, and we consider several different scenarios: growth consistent with individual states' experiences over the last ten years, growth consistent with the national experience over the last ten years, and each of these scenarios reduced by one percent.

Total assets *T+1* years in the future, A_{T+1}, are therefore given by

$$1.0171A_T + \left(AR^* - (c^{NC} - c^{employee})\right)(1+g)^T W_0^{total} - B_T\ ,$$

where *AR** is the amortization rate (our primary object of interest), c^{NC} is the normal cost rate (service cost relative to wages), $c^{employee}$ is the employee contribution rate, g is the assumed growth rate in the state's economy and government sector, W_0^{total} is total wages today, and B_T is the deflated time-*T* benefit cash flows to retirees currently recognized under the accounting methodology (ABO or EAN). We search for the amortization rate *AR** such that assets thirty years in the future are just sufficient to pay the remaining recognized benefit payments owed to current workers, i.e., such that

$$A_{30} = \sum_{t=0}^{\infty} \frac{B_{30+t}}{(1+r)^{t+1}},$$

where *r* is picked to match the 21 year TIPs rate of 1.71%. If the assets together with expected investment earnings are insufficient to pay remaining future benefit obligations, then the algorithm tries a higher employer contribution over the next thirty years. If they are more than sufficient, then we try a lower rate. The algorithm searches until it finds the rate that just fully amortizes the legacy liabilities over the thirty year period.

D. Incorporating "Tiebout" Migration

If a state has to raise taxes and/or cut services more than other states to pay for legacy pension obligations, it makes residency in the state relatively unattractive. This affects the marginal decisions of both state residents considering out-migration and other states' residents considering in-migration. While this should be at least partially reflected in lower property values, it also reduces the state's rate of economic growth, as taxpayers choose to locate in states that provide better government services at lower prices.

We model this change in economic growth rates in response to changes in taxes and services using a linear specification. Specifically, we assume that an increase in the revenues raised by state and local governments, and/or a reduction in the services they provide, measured as a fraction of GSP, relative to the national average, reduces the real growth rate of state GSP. That is, we assume that state *i*'s adjusted GSP and public sector growth rate is given by

$$g_i^* = g_i - \beta\left(\frac{\left(AR_i^* - c_i^{old}\right)W_i^{total}}{GSP_i} - \frac{\sum_{states}\left(AR_j^* - c_j^{old}\right)W_j^{total}}{\sum_{states} GSP_j}\right),$$

where g is the growth rate absent Tiebout effects, β is the sensitivity of GSP growth to tax increases and/or service cuts, AR^* is the amortization rate accounting for Tiebout effects, c^{old} is the old contribution rate to pension plans, and W^{total} is total public sector wages. In our primary analysis we assume that an increase in taxes and fees (or reduction in services) one percent of GSP greater than the average states' reduces the GSP growth rate by two percent (β = 2). We also consider scenarios in which states' GSP growth rates are more or less sensitive to relative tax increases and/or revenue reductions (β = 3 and β = 1, respectively).

E. Accounting for Municipal Debt

States may use off-balance-sheet debt, in the form of pension underfunding, as a complement (not substitute) to municipal debt. Alternatively, the revenue demands of dramatically underfunded pension plans may force these plans' states to finance their operations at least partly through municipal borrowing. In either case, ignoring municipal debt understates the dispersion in the states' financial well-being. There are limits to the extent to which states that are currently issuing a high volume of bonds can continue to do so, while states with very little general obligation or pension obligation bond debt could begin to pay some obligations through municipal debt issuance.

A more sophisticated analysis of the amortization of states legacy pension liabilities accounts for variation in municipal indebtedness. We do this by adjusting current pension fund assets to reflect differences in non-pension debt. Specifically, we replace state *i's* pension fund asset with its "adjusted assets," given by

$$A_i^* = A_i - D_i + \left(\frac{\sum_{states} D_j}{\sum_{states} GSP_j}\right) GSP_i.$$

If a state's aggregate municipal debt relative to GSP exceeds aggregate national municipal debt relative to national GDP, we reduce its pension fund assets to reflect the difference. Conversely, if a state's debt is relatively small relative to its economy, we add the difference to its pension fund assets.

F. Amortizing Legacy Liabilities Under a Soft Freeze

Under the soft freeze scenarios, we calculate the amortization rate, relative to wages or GSP, at which states and localities need to contribute for the next 30 years to completely amortize the legacy liabilities associated with old DB plans, under the assumption that all new hires participate in Social Security and a DC plan.

New employees are assumed to receive pension benefit contributions from their employers totaling 16.2%—6.2% in the form of employer contributions to Social Security, and 10% in the form of higher wages, employer contributions to a defined contribution plan, or some mix of the two. That is, we effectively assume that new employees are compensated for the loss of DB pension plans with an increase in other total compensation of 10%, plus inclusion in Social Security if not previously enrolled. Salaries are adjusted up 6.2% for new hires in entities that were not previously part of Social Security, to offset the effective pay cut these workers receive when they are asked to contribute to the system. The employer contribution to the old DB plans is the portion of the total employer payroll that does not go to new workers.

Future benefit payments are funded using plan assets and investment earnings, new contributions from plan participants, and new contributions from the states and localities. State and local contributions to old plans are equal to their total contribution to all plans, less their contribution to new plans. Total assets *T+1* years in the future, A_{T+1}, are consequently given by

$$1.0171A_T + c^{old} \cdot W_T^{old} + AR^*(1+g)^T W_0^{total} - c^{new}\left((1+g)^T W_0^{total} - W_T^{old}\right) - B_T^{PVB},$$

where c^{old} is the employee contribution rate of old workers to their *DB* plans, W^{old} is these workers' wages, c^{new} is the effective employer contribution rate for new hires on DC plans, and B_T^{PVB} is the total benefit cash flows paid to retirees. The first term represents principle and investment earnings on the previous year's assets, the second term is the contributions of working plan participants, the third term is the total contribution of employers to pension plans, both old and new, the fourth term is the employer contributions that go to new workers' DC plans, and the last term is the payout to DB plan beneficiaries.

At the end of 30 years we require that plan assets, in conjunction with the negligible future contributions on the salaries of the remaining active workers covered by the old DB plan (employee, plus employer at the DB contribution rate), are just sufficient to pay the plan's remaining liabilities. That is, we require that

$$A_{30} = \sum_{t=0}^{\infty} \frac{B_{30+t}^{PVB} - (c^{old} + c^{new})W_{30+t}^{old}}{(1+r)^{t+1}}.$$

G. Amortizing Legacy Liabilities Under a Hard Freeze

We calculate the amortization rate under the hard freeze scenarios in the exact same way, except that we 1) use the ABO instead of the PVB to determine cash outflows to retired plan participants; 2) assume that participants in the old DB plans stop contributing to these plans, as they are no longer accruing new benefits; and 3) assume that participants in the old DB plans also receive new DC plans, and Social Security if they previously lacked it, and that employers contribute to these plans at the same rate that they do for new hires.

That is, total assets *T+1* years in the future, A_{T+1}, are given by

$$1.0171A_T + (AR^* - c^{new})(1+g)^T W_0^{total} - B_T^{ABO}.$$

We again search for the amortization rate *AR** such that assets thirty years in the future are just sufficient to pay the remaining benefit payments owed to participants of the old, frozen DB plans, i.e., such that

$$A_{30} = \sum_{t=0}^{\infty} \frac{B_{30+t}^{ABO}}{(1+r)^{t+1}}.$$

IV. Results

In this section, we discuss the results. Section A presents our calculations of the service costs, the true present value of newly accrued benefits. Section B presents calculations of the necessary contributions for pension systems to be fully funded in 30 years' time, assuming no policy changes. Section C discusses how that calculation would vary if the tax base shifts from states that have to raise taxes more to states that have to raise taxes less. Section D presents the results that consider the impact that limits to debt issuance might have on the calculations. Section E discusses the effects of soft and hard freezes on the calculations.

A. Service Costs

If governments are conforming to GASB standards and paying the ARC, then they are paying this present value under their returns-based discount rates, as well as making some payments towards amortizing unfunded liabilities. Of course, as explained in section II, not all states pay the ARC. Furthermore, even states that do pay the ARC are measuring new benefit promises using the expected returns to discount the pension promises.

We begin with calculations of the service costs as a percent of payroll for state and local systems aggregated to the state level, under both stated discount rates and Treasury discount rates, and using both the ABO and the EAN methods. Most state and local governments themselves use the EAN method, which as explained in Section III recognizes liabilities earlier in worker careers in such a way as to make the service cost a constant fraction of wages over the worker's lifetime, but it is the ABO method that reflects the actual market value of benefits earned in a given year. Compared to the EAN method, the ABO method involves higher service costs but lower recognized liabilities today.

Figure 1 provides a graphical representation of how the service costs are calculated. The top two lines in Figure 1 show the year by year forecast of the expected benefit payments recognized under the EAN (solid line), and those recognized the previous year under the EAN for the same workers (dashed line). [17] The bottom two lines show the expected benefit payments recognized under the ABO (dotted line) and those recognized the previous year under the ABO for the same workers (lowest line). The present value of the difference in the top two lines yields the EAN service cost, and the present value of the difference in the bottom two lines yields the ABO service cost. Note that these service cost calculations exclude Social Security. In the analysis presented our main results tables, Social Security is treated as costing 6.2% of payroll for both employer and employee, and we assume that employers who newly enroll employees on Social Security must provide a 6.2% pay increase.

Table 3 provides the service costs for each state under each of the two liability recognition methods (EAN and ABO) and each of the two discount rate methods (state-chosen and Treasury yield curves). Again, each row represents the total of all state and local government systems within a given state. In total, ABO service costs under state-chosen discount rates are 17.8% of payroll, whereas under Treasury rates they are 29.5% of payroll, a difference of 11.7% of payroll. EAN service costs under state-chosen discount rates are 13.9% of payroll, but under Treasury rates they are 28.2% of payroll, a difference of 14.3% of payroll.[18] The true present value of new benefit accruals thus averages 12-14 percent of payroll more than the costs recognized under GASB.

The 28.2-29.5% of payroll cost of the DB pensions compares to total (employer plus employee) contributions to DB plans of 17.7%. Those contributions are roughly equal to ABO

[17] A similar analysis of the year by year benefit payment recognized under the PVB, which accounts for all future wage growth and service accruals, and those recognized the previous year for the same workers, yields essentially no difference, providing additional validation of the model.

[18] The difference between the ABO and EAN service costs essentially represents the difference between the growth, due to one year's less discounting, of the EAN and ABO liabilities.

service costs under state-chosen discount rates, but are 10-12 percentage points of payroll less than service costs calculated using Treasury rates.

The table is sorted in descending order of the ratio of service costs under the ABO method using Treasury discounting to actual contributions made. The ratio of service costs under the EAN method using Treasury discounting is also provided. The table shows that in all cases except one (Indiana under the EAN method), contributions in 2009 fell short of the present value of new benefit promises when measured under the Treasury rate. In Oregon, the true present value of benefits is 3.2-3.6 times the amount contributed, and in thirteen states it is over 2 times on both the ABO and EAN recognition methods, and in two additional states it is over 2 times the ABO but not the EAN service cost.[19]

Appendix Figure 1 shows the close relationship between our calculations of service costs and the plans' benefit factors. Initial benefit payments are proportional to final wages, service at the time of retirement, and the benefit factor employed in the benefits calculation. The primary determinant of annual service costs is therefore not surprisingly the product of total wages and the benefit factor.

B. Economically Required Contributions without Policy Changes

Paying the full present value of the service cost would not address the unfunded liability. In fact, the unfunded liability would still continue to grow, just as any debt that is not being serviced continues to grow. The left two vertical panels of Table 4 summarize the contributions necessary to pay the present value of new benefits and amortize today's unfunded liabilities over 30 years. In other words, the goal is to end up with fully funded systems in 30 years. In Table 4, the present value of new promises and the amortization of unfunded legacy liabilities are calculated under the Accumulated Benefit Obligation (ABO) accrual method. In the appendix, we present similar analysis using the EAN accrual method, which results in greater unfunded liabilities that must be amortized, but lower service costs that must be paid as they are accrued.

The first column of Table 4 shows that if each state is given its 10-year average real GSP growth rate going forward, contributions must rise in aggregate to 40.7% of payroll per year across public employee pension plans in the United States. The mean is 38.7%, and the standard

[19] If a state or local government contributes the full present value of new services accruals, but undertakes no actions to reduce the unfunded liability, then the unfunded liability continues to grow at the risk-free rate, adjusted for any exceptional returns realized by the fund's assets.

deviation is 7.0%. North Carolina requires the smallest contribution as a percentage of payroll, 24.7%. Colorado requires the largest, 53.9%.[20] As a share of tax revenue, the weighted average contribution requirement is 22.7%, and as a share of total own-revenue it is 12.7%. As a share of GDP the overall required contribution is 2.0%. The contribution to pensions per resident household must rise to $2,339, with Indiana requiring only $1,211 and New York requiring the largest annual per-household contribution: $3,989.

The column under "Total Required Contribution: 10yr Average GSP – 1%" models a 1% smaller GSP growth in each state. This raises required contributions as a share of own-revenue from 14.2% to 14.9%, as slower growth implies larger contributions today as a share of revenues, payroll, and GSP.

Appendix Table 1 provides several robustness checks. In the first vertical panel of Appendix Table 1, we eliminate the state-by-state variation in GSP growth rates and assume that all state economies grow at the GSP-weighted average real U.S. GSP growth rate from the past 10 years, 1.98%. Harmonizing the growth rates across states has little effect on the averages. However, eliminating the state-by-state variation in growth rates does reduce the variability of state outcomes. For example, under its own historical GSP growth rate, state and local funds in Illinois must contribute 20.2% of own revenues to pensions, the highest of any state.[21] Under the national average GSP growth rate, the highest contribution required by any state as a share of total own revenue is New Mexico at 19.2%. The standard deviation falls from 3.3% to 3.1%.

In the second vertical panel of Appendix Table 1, we repeat the first columns of Table 4 but under the EAN method instead of the ABO method. This adjustment raises the required contributions. In this specification, the plans must be fully funded on an EAN basis at the end of 30 years, and the EAN recognizes a greater portion of total expected future benefit payments.

The left two vertical panels of Table 4 show the total necessary contributions, but of course state and local governments are already making contributions, so an important question is how much the contributions must rise. The right two vertical panels presents the required contribution increases. Here we see that the weighted-average contribution increase across all pension systems is 24.3% of payroll. That means that state and local governments need to come

[20] This is after the application of the COLA decreases implemented by Colorado in 2010. Similarly, the 2010 COLA decreases for Minnesota were also implemented.
[21] This accounts for the higher retirement ages and other changes implemented for new workers in the Illinois pension reform of 2010.

up with an additional 24.3% of worker salaries if they want to start paying the full present value of new benefit promises and amortize unfunded liabilities over 30 years to achieve full funding at that point. These increases amount to 13.6% of tax revenue, 8.5% of total own revenue, and 1.2% of GSP per year. On a per-household basis, the required increase is $1,398 per U.S. household per year. If GSP growth is 1 percentage point slower, the required per-household contribution increase is 8.6% larger.

Table 5 shows the required contribution increases by state, in descending order of the required increase per resident household. In thirteen states, the necessary increases are more than $1,500 per household per year, and in five states they are more than $2,000 per household per year. At one extreme, New Jersey would need to raise an additional $2,475 per household, which amounts to 1.7% of GSP. At the other extreme, Indiana requires increases of only $329 per household or 2.0% of total own revenue.

C. Effects of a Mobile Tax Base

In this section we incorporate the possibility that taxpayers will respond to attempts by states to increase taxes and/or cut services. Specifically, an increase in the revenues raised by state and local governments, and/or a reduction in the services they provide, measured as a fraction of GSP, relative to the national average, is assumed to reduce the real growth rate of state GSP. Effectively, growth is redistributed from states that have to raise taxes and cut services a lot to those that have to raise taxes and cut services less.

Appendix Table 2 shows that incorporating a Tiebout parameter of 2 has only a very small impact on the average contribution increases, although this does increase the standard deviation and the extremes. For example, the standard deviation of the contribution increase as a percentage of own-revenue is 2.7% without this Tiebout effect (see Table 4) and 3.4% with the Tiebout effect. The small differences in averages, e.g. 25.2% of payroll with Tiebout and 24.3% without, are due to the fact that the better states have higher growth rates and therefore rely more on bigger payments at the end of the amortization period.

Appendix Table 3 lists the required contribution increases by state in decreasing order of per household dollar amounts, inclusive of these tax base mobility effects. For example, New Jersey now has to raise contributions by $2,763 per household, as opposed to $2,475 in Table 5. The extent to which systems are affected is related to the required increase as a share of GSP in Table 5. Ohio and Oregon therefore see more substantial tax base mobility effects, with Ohio rising from $2,051 per household without these effects (Table 5) to $2,541 per household including the effects. Oregon's requirements rise from $2,140 per household excluding the Tiebout effects (Table 5) to $2,409 per household including the effects. Outside of the top 10 states, there is relatively little effect. Inclusive of the mobility effects, the states in the best shape have to increase contributions even less.

The analysis in Appendix Tables 2 and 3 assumes that an increase in revenues or reduction in services of one percent of GSP greater than the average states' reduces the state's GSP growth rate by one percent. The top panel of Figure 2 displays the results for the states facing the largest increases under four different coefficients for these mobility effects: 0 (the baseline), 1, 2 (the scenario presented above), and 3. The dispersion among states is increasing with the mobility parameter. At sufficiently high parameterizations there would be no level of taxation sufficient for Ohio or Oregon to amortize their legacy liabilities. The tax burdens and service cuts become so onerous on residents that decide to stay in the state that everyone immediately moves out. The bottom panel of Figure 2 displays the results for states facing the smallest required increases. For public systems in Utah and Indiana, the Tiebout effects all but eliminate the required contribution increases.

D. Debt Issuance Limitations

Some states have issued substantial amounts of general obligation or pension bonds in order to close deficits and meet pension contributions. As shown in Table 6, state and local governments in states such as Kentucky, Massachusetts, and New York have debt of more than 25% of GSP when aggregated to the state level. The state of Illinois routinely makes its current pension contributions by issuing (taxable) bonds. If there is no limit on debt issuance then states could effectively pay for pensions by borrowing for a long time, at least until the costs of servicing the debt began to affect the budget in a serious way.

Municipal debt is positively correlated with pension underfunding. Appendix Figure 2 shows this correlation graphically. Each additional dollar in municipal debt is associated with an additional 67 cents in ABO pension underfunding, and this relation is highly significant, with a test-statistic of 3.61. Off-balance-sheet debt in the form of pension underfunding does appear to be a complement to municipal debt.

Table 6 shows the effects of the limits on debt issuance described in Section III.E above for the states with the most positive and most negative debt effects. We model these effects not as a restriction *per se*, but as a reduction in pension fund assets to reflect the difference between a state's aggregate municipal debt relative to GSP and the ratio of aggregate national municipal debt to national GDP. This is the level of pension fund assets that plans would have if highly indebted states used pension fund assets to reduce their indebtedness down to the national average, while states with low levels of debt borrowed from muni markets and used the capital raised to fund their pension plans.

The debt effects we model increase the share of GSP that must be devoted to pension contributions in the most indebted states by a factor of 0.2-0.3 percent of GSP. In contrast, states with very little state and local on-balance-sheet debt could conceivably issue some debt to meet pension funding obligations, and for the states with the least current debt as a share of GSP, this reduces the share of GSP that must be devoted to pensions by 0.2 percentage points.

E. Effects of Soft and Hard Freezes

In this section we consider the impacts of soft and hard freezes. The top panel of Table 7 shows the necessary contribution increases under no Tiebout effects for a soft freeze, and the bottom panel shows the analogous calculations for a hard freeze.

The top panel of Table 7 shows that soft freezes have moderate revenue-saving effects. The required increases decline from $1,398 to $1,223 per household (excluding Tiebout effects). For Alaska and Utah, the figures going into the top panel of Table 7 are identical to those from the baseline analysis, as these states have already implemented soft freezes.

Soft freezes under the above parameters reduce required contribution increases for all but seven states. The exceptions are states that have relatively high employee contribution rates with low Social Security coverage: Ohio, Illinois, Colorado, Massachusetts, Missouri, Louisiana and Maine. In Ohio, for example, shifting new workers to a DC plan actually increases total revenue demands by $489 per household, from an increase of $2,051 to an increase of $2,540 per household. This can be understood by noting that currently, employees in Ohio systems contribute about 10% of pay and employers contribute about 11% of pay, with very little Social Security participation. If new workers are shifted to a DC plan under the modeled assumptions, employers will have to devote almost all of the 11% of pay they would otherwise have contributed to DB plans to the DC plan, plus they will have to pay 12.4% for Social Security inclusion. The new employees' contributions now go towards their DC plan and cannot be used in the DB system. This analysis does not reflect one major advantage of DC plans, namely that their transparency ensures there will be no unfunded liabilities or unrecognized public sector borrowing through pension promises.

Proposals for hard freezes of defined benefit (DB) pensions in the public sector have not reached the mainstream, but it is useful to examine the extent of cost savings that could potentially be achieved. The bottom panel of Table 7 shows the necessary contribution increase calculations including both a hard freeze and the Tiebout mechanism examined in the previous section. We assume that in addition to the new workers, all future work by existing employees is compensated on the DC plan. Specifically, we assume DB plans cost employers 10% of wages, in the form of plan contributions, higher salaries, or some combination of the two. We also assume that employees from plans not previously included in Social Security receive an additional 6.2% salary increase, to offset the effective salary reduction represented by future employee contributions to this plan. Under a hard freeze, the DB cash flows decline from the PVB cash flows to the ABO cash flows.

The bottom panel of Table 7 shows that for the baseline GSP growth scenario, contributions now need to rise by only 4.9% of total own revenue, instead of 8.5% in Table 4. Contribution increases per resident household under a hard freeze are still $805.

For all states, a hard freeze generates a decline in required contribution increases, although substantial revenue increases or tax cuts are still required. If employees get DC plans instead of DB accruals, they will likely be compensated with employer contributions to these DC plans. In our analysis, we have calculated this cost in a similar way to the cost calculations performed for new hires under soft freezes. If public employees require even higher levels of compensation for the switch to DC plans then these cost savings would be even more muted.

V. Conclusion

This paper proposes an alternative measurement for the quality of public pension funding, namely the extent to which state and local governments will have to raise taxes or cut spending to pay for pension obligations. Specifically, we calculate how much states have to increase revenues or cut spending to pay new pension promises to existing employees and pay down unfunded legacy liabilities over the next 30 years. Given blurred lines between what is a state obligation and what is a local obligation, our analysis considers all state and local government DB plans within a state as a unit, and compares that to all revenue sources of state and local governments within the state.

One theme that emerges is that substantial revenue increases or spending cuts are required to pay for pension promises to public employees, even if pension promises are frozen at today's levels. The cost savings that states would realize through soft or hard freezes depends on the current level of generosity of the plans, as well as current levels of employee contributions and the generosity of the DC plan that would replace the DB plan. Hard freezes, even with the relatively generous DC plans that we model (an employer cost of 10% of pay, plus Social Security for all employees fully paid for by the employer) reduce revenue demands for all states. Soft freezes with similar DC plan modeling reduce revenue demands for all but seven states with relatively large employee contributions and relatively low current Social Security coverage. Achieving cost savings under a soft freeze in those states would require either less generous DC plans or forcing public employees to bear a share of the cost of Social Security participation.

A significant finding of our analysis is that the GASB rules significantly undervalues the cost of providing DB plans to state workers, as the true present value of new benefit accruals averages 12-14 percent of payroll more than the costs recognized under GASB. These distortions can generate conflicting interests between state and local governments. For example, in states where the state government is responsible for paying the unfunded liability for plans covering local workers such as teachers GASB accounting forces states to subsidize local government employees. In these situations the state effectively must bear the expense of the extra 12-14 percent of payroll that the plans actually cost, potentially encouraging excessive hiring at the local level. State governments typically bear that burden by taking high levels of investment risk and requiring taxpayers to underwrite downside insurance. Conversely, in some states the state government negotiates the pension benefits of local employees, but requires local governments to fund these benefits, as happens for example with municipal police and fire systems in Illinois. In that case, the state essentially forces the local governments into a similar arrangement.

We have modeled some degree of tax base sensitivity to the required increase in revenues or cuts in spending. An interesting avenue for future research would be to further examine how these effects would operate at the local level, as cities and counties may be more exposed to the threat of citizens "voting with their feet" than states. The extent to which such migration might affect the solvency of local governments is an important area for future research.

References

Alesina, Alberto, and Roberto Perotti. 1995. "The Political Economy of Budget Deficits." *IMF Staff Papers* 42, 1-31.

Beshears, John, James Choi, David Laibson, and Brigitte Madrian. 2011. "Behavioral economics perspectives on public sector pension plans." *Journal of Pension Economics and Finance* 10(2): 315-336.

Bohn, Hening. 2011. "Should public retirement plans be fully funded?" *Journal of Pension Economics and Finance* 10(2): 195-219.

Bureau of Economic Analysis. 2010. "GDP by State," http://www.bea.gov/regional/gsp/.

Bader, Lawrence N. and Jeremy Gold. 2004. "The Case Against Stock in Public Pension Funds." Pension Research Council Working Paper.

Black, Fischer. 1989. "Should You Use Stocks to Hedge Your Pension Liability?" *Financial Analysts Journal* 45(1): 10-12.

Bodie, Zvi. 1990. "The ABO, the PBO, and Pension Investment Policy." *Financial Analysts Journal* 46: 27-34.

Bodie, Zvi, Marcus, Alan, Merton, Robert. 1988. "Defined benefit vs. defined contribution pension plans: what are the real trade-offs?" In *Pensions in the U.S. Economy*, eds. Zvi Bodie, John Shoven, and David Wise, 139-162. Chicago: University of Chicago Press.

Brown, Jeffrey and David Wilcox. 2009. "Discounting State and Local Pension Liabilities." *American Economic Review* 99(2): 538-542.

Comprix, Joseph, and Karl A. Muller. 2011. "Pension plan accounting estimates and the freezing of defined benefit pension plans." *Journal of Accounting and Economics* 51(1): 115-133.

D'Arcy, Stephen P., James H. Dulebohn, and Pyungsuk Oh. 1999. "Optimal Funding of State Employee Pension Systems." *Journal of Risk and Insurance* 66(3): 345–80.

Friedberg, Leora. 2011. "Labor Market Aspects of State and Local Retirement Plans: A review of evidence and a blueprint for future research." *Journal of Pension Economics and Finance* 10(2).

Gold, Jeremy. 2002. "Risk Transfer in Public Pension Plans." Working Paper 2002-18, Wharton Pension Research Council.

Gold, Jeremy, and Gordon Latter. 2008. "The Case for Marking Public Pension Plan Liabilities to Market." Working Paper.

Lucas, Deborah and Stephen P. Zeldes. 2006. "Valuing and Hedging Defined Benefit Pension Obligations: The Role of Stocks Revisited." Mimeo: Columbia University.

Lucas, Deborah and Stephen P. Zeldes. 2009. "How should public plans invest?" *American Economic Review* 99(2): 527–532.

Milevsky, Moshe, and Keke Song. 2010. "Do Markets Like Frozen Defined Benefit Pension Plans? An Event Study." *Journal of Risk and Insurance* 77(4): 893-909.

Novy-Marx, Robert, and Joshua Rauh. 2008. "The Intergenerational Transfer of Public Pension Promises." NBER Working Paper #14343.

Novy-Marx, Robert, and Joshua Rauh. 2009. "The Liabilities and Risks of State-Sponsored Pension Plans." *Journal of Economic Perspectives* 23(4), 191-210.

Novy-Marx, Robert, and Joshua Rauh. 2011a. "Public Pension Liabilities: How Big Are They and What Are They Worth?" *Journal of Finance* 66(4): 1207-1246.

Novy-Marx, Robert and Joshua Rauh. 2011b. "The Crisis in Local Government Pensions in the United States." In *Growing Old*: *Paying for Retirement and Institutional Money Management after the Financial Crisis*, eds. Robert Litan and Richard Herring, Brookings Institution.

Pennacchi, George, and Mahdi Rastad. 2011. "Portfolio allocation for public pension funds." *Journal of Pension Economics and Finance* 10(2): 221-245.

Persson, Torsten, and Guido Tabellini. 2000. *Political Economics*, MIT Press.

Poterba, James, Joshua Rauh, Steven Venti, and David Wise, 2007. "Defined Contribution Plans, Defined Benefit Plans, and the Accumulation of Retirement Wealth." *Journal of Public Economics* 91: 2062-2086.

Rauh, Joshua and Irina Stefanescu. 2009. "Why Are Firms in the United States Abandoning Defined Benefit Plans?" *Rotman International Journal of Pension Management* 2(2): 18-26.

Samwick, Andrew, Skinner, Jonathan. 2004. "How will 401(k) plans affect retirement income?" *American Economic Review* 94: 329–343.

Schieber, Syl. 2011. "Political economy of public sector retirement plans." *Journal of Pension Economics and Finance* 10(2): 269-289.

Shoag, Daniel. 2011. "The Impact of Government Spending Shocks: Evidence on the Multiplier from State Pension Plan Returns." Working Paper, Harvard University.

Tiebout, Charles. 1956 "A Pure Theory of Local Expenditures." *Journal of Political Economy* 64(5): 416-424.

U.S. Census Bureau. 2010a. "U.S. Census of State and Local Retirement Systems, Fiscal Year 2008." http://www.census.gov/govs/retire/

U.S. Census Bureau. 2010b. "State Government Finances 2009." http://www2.census.gov/govs/state/09statess.xls

Figure 1: One-Year Change in Recognized Cash Flow Promises for Non-Retiring Workers

This figure provides a graphical representation of how service costs are calculated. The top two lines in show the year by year forecast of the expected benefit payments recognized under the EAN (solid line), and those recognized the previous year under the EAN for the same workers (dashed line). The bottom two lines show the expected benefit payments recognized under the ABO (dotted line) and those recognized the previous year under the ABO for the same workers (lowest line). The present value of the difference in the top two lines yields the EAN service cost, and the present value of the difference in the bottom two lines yields the ABO service cost.

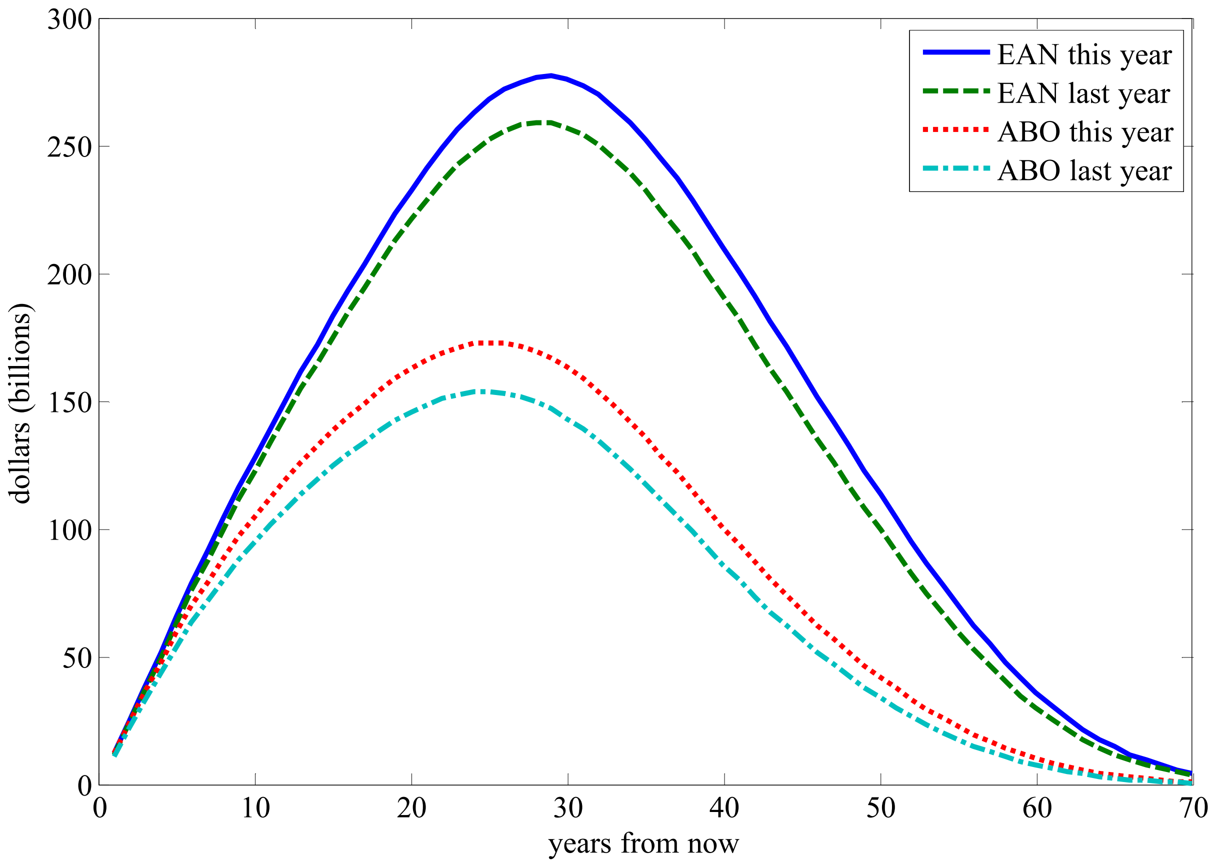
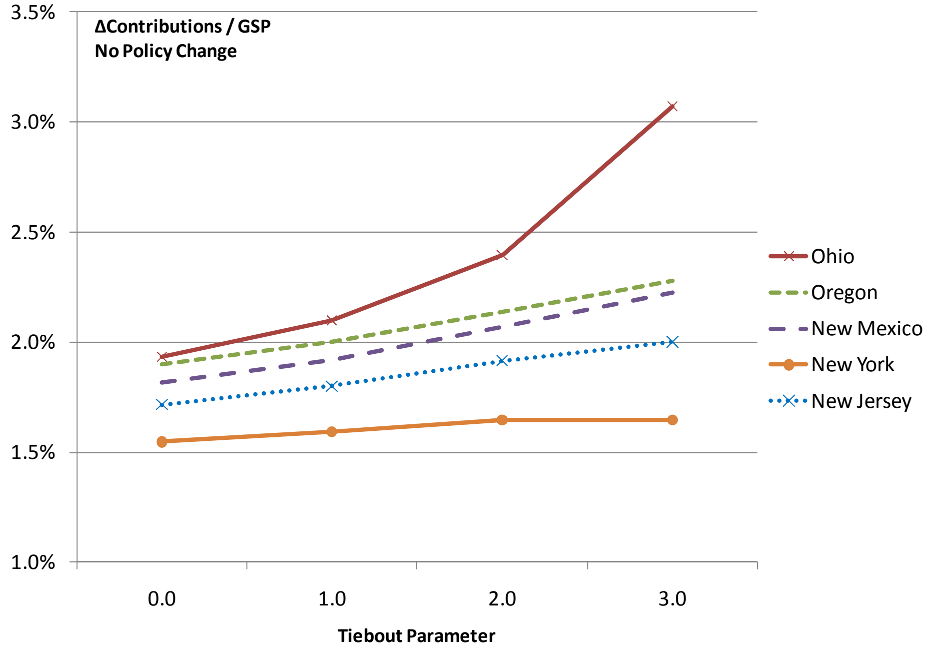


Figure 2: Effects of Tiebout Parameters on Required Contribution Increases

The figures show required increase in government contributions as a share of GSP to arrive at a fully funded pension system in 30 years on an ABO basis, assuming no benefit changes, under different Tiebout parameters. In the top figure, only the five states with the largest necessary contribution increases are shown. In the bottom figure, only the five states with the smallest necessary contribution increases are shown. The Tiebout parameter is the decline in the GSP growth rate per additional point of GSP raised in state government revenue.



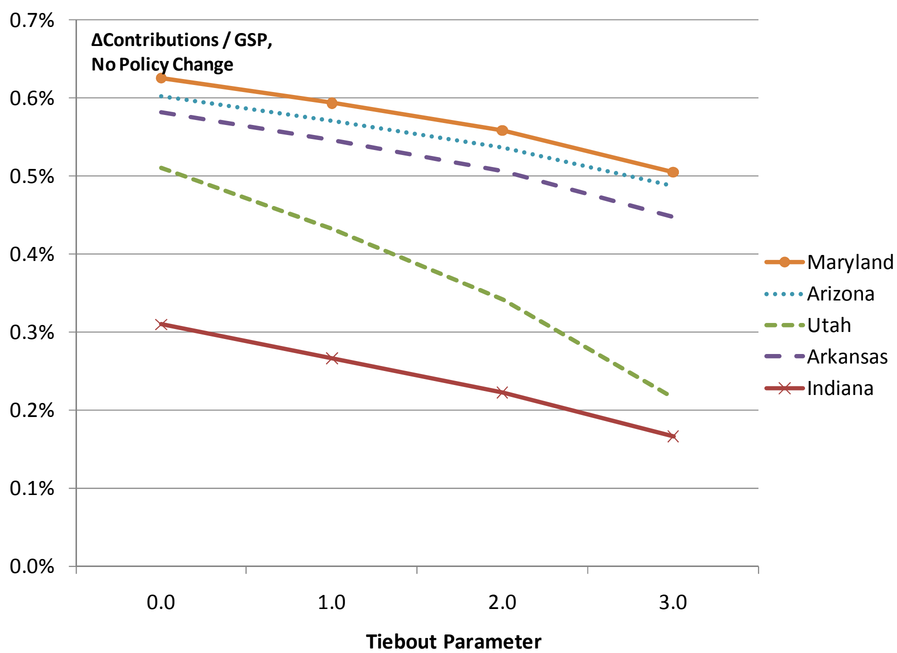


Table 1: Summary Statistics: Contributions, Payroll, and Revenues (2009) for State and Local Systems, Aggregated to the State Level

	mean	std dev	total	min		max	
Tax Revenue	$24.3	$30.8	$1,215.1	$2.5	SD	$160.1	CA
Total Own Revenue	$38.9	$47.9	$1,947.4	$4.3	SD	$262.0	CA
Gross State Product (GSP)	$281.0	$337.5	$14,051.7	$25.4	VT	$1,891.4	CA
Households (M)	2.36	2.62	117.85	0.21	WY	14.22	CA
Payroll							
$ billions	$13.6	$18.6	$678.0	$1.2	VT	$108.1	CA
as share of Tax Revenue	54.3%	10.4%	55.8%	35.3%	NE	79.2%	AL
as share of Total Own Revenue	32.8%	5.7%	34.8%	17.4%	NE	42.5%	TX
as share of Gross State Product	4.6%	0.8%	4.8%	2.9%	NE	6.2%	NM
per household	$5,446	$1,310	$5,753	$3,507	AR	$8,772	WY
Total Government Contributions (Including Social Security)							
$ billions	$2.2	$3.3	$110.9	$0.2	ND	$19.5	CA
as share of Payroll	16.5%	3.9%	16.4%	9.0%	TX	26.7%	RI
as share of Tax Revenue	8.9%	2.6%	9.1%	4.7%	ND	14.8%	AL
as share of Total Own Revenue	5.4%	1.6%	5.7%	2.8%	CO	9.3%	RI
as share of Gross State Product	0.8%	0.2%	0.8%	0.4%	CO	1.3%	RI
per household	$892	$280	$941	$463	CO	$1,739	NY
Total Government Contributions (Excluding Social Security)							
$ billions	$1.6	$2.5	$80.7	$0.1	ND	$15.2	CA
as share of Payroll	11.6%	4.3%	11.9%	3.3%	NC	22.4%	NV
as share of Tax Revenue	6.3%	2.5%	6.6%	2.1%	NC	12.1%	NV
as share of Total Own Revenue	3.8%	1.6%	4.1%	1.3%	NC	7.6%	NV
as share of Gross State Product	0.5%	0.2%	0.6%	0.2%	NC	1.0%	RI
per household	$628	$275	$684	$173	NC	$1,291	NY
Total Employee Contributions (Including Social Security)							
$ billions	$1.4	$1.9	$69.1	$0.1	VT	$12.6	CA
as share of Payroll	10.7%	2.6%	10.2%	2.6%	NV	15.2%	NM
as share of Tax Revenue	5.8%	2.0%	5.7%	1.4%	NV	10.7%	NM
as share of Total Own Revenue	3.5%	1.1%	3.5%	0.9%	NV	6.0%	NM
as share of Gross State Product	0.5%	0.2%	0.5%	0.1%	NV	0.9%	NM
per household	$577	$185	$586	$135	NV	$1,006	WY
Total Employee Contributions (Excluding Social Security)							
$ billions	$0.8	$1.3	$38.8	$0.0	OR	$8.3	CA
as share of Payroll	5.8%	2.5%	5.7%	0.1%	OR	11.6%	MA
as share of Tax Revenue	3.1%	1.5%	3.2%	0.1%	OR	6.5%	OH
as share of Total Own Revenue	1.9%	0.9%	2.0%	0.0%	OR	4.1%	OH
as share of Gross State Product	0.3%	0.1%	0.3%	0.0%	OR	0.6%	OH
per household	$312	$154	$330	$6	OR	$644	AK

Table 2: Contributions, Payroll, and Revenues for State and Local Systems, Aggregated to State Level

	Total Payroll ($B)	Own Revenue ($B)	GSP ($B)	Government Contributions Incl Social Security			
				% of Payroll	% Own Revenues	% of GSP	per household
New York	$65.8	$197.7	$1,093.2	19.9%	6.6%	1.2%	$1,738.8
Rhode Island	$2.4	$6.8	$47.8	26.7%	9.3%	1.3%	$1,557.3
Hawaii	$3.7	$9.3	$66.4	19.1%	7.7%	1.1%	$1,436.4
Virginia	$17.5	$47.4	$408.4	23.8%	8.8%	1.0%	$1,374.0
California	$108.1	$262.0	$1,891.4	18.0%	7.4%	1.0%	$1,368.8
Alaska	$2.3	$10.8	$45.7	14.5%	3.1%	0.7%	$1,234.7
Illinois	$29.3	$76.8	$630.4	20.6%	7.9%	1.0%	$1,215.3
New Mexico	$4.7	$11.9	$74.8	19.8%	7.8%	1.2%	$1,194.0
Connecticut	$9.0	$26.2	$227.4	17.8%	6.1%	0.7%	$1,180.6
Nevada	$5.2	$15.3	$126.5	22.4%	7.6%	0.9%	$1,147.2
New Jersey	$26.9	$65.5	$483.0	13.4%	5.5%	0.7%	$1,078.0
Alabama	$10.2	$25.6	$169.9	18.7%	7.4%	1.1%	$1,050.8
Maryland	$11.5	$36.9	$286.8	19.5%	6.1%	0.8%	$1,026.0
Oklahoma	$6.3	$20.4	$153.8	23.2%	7.1%	0.9%	$1,022.2
Wyoming	$1.8	$6.7	$37.5	11.3%	3.1%	0.6%	$987.3
West Virginia	$2.8	$10.2	$63.3	24.1%	6.7%	1.1%	$980.5
Mississippi	$5.9	$15.6	$95.9	18.9%	7.1%	1.2%	$973.0
Washington	$16.9	$47.2	$338.3	14.7%	5.3%	0.7%	$968.3
Louisiana	$8.8	$26.3	$208.4	17.5%	5.9%	0.7%	$891.3
Indiana	$10.8	$37.1	$262.6	20.2%	5.9%	0.8%	$882.1
Massachusetts	$13.5	$46.9	$365.2	16.5%	4.7%	0.6%	$877.6
South Carolina	$8.9	$26.5	$159.6	17.1%	5.7%	0.9%	$862.5
Oregon	$8.7	$23.8	$165.6	14.5%	5.3%	0.8%	$862.1
Kansas	$6.8	$18.4	$124.9	13.6%	5.0%	0.7%	$846.6
Minnesota	$13.5	$35.5	$260.7	12.7%	4.8%	0.7%	$843.8
Utah	$4.4	$15.9	$112.9	20.2%	5.6%	0.8%	$826.9
Arizona	$13.3	$32.6	$256.4	15.3%	6.2%	0.8%	$799.1
Missouri	$10.8	$30.0	$239.8	16.8%	6.0%	0.8%	$787.4
Michigan	$16.8	$56.9	$368.4	17.9%	5.3%	0.8%	$781.3
Florida	$28.6	$109.5	$737.0	19.3%	5.0%	0.7%	$771.8
Iowa	$6.4	$19.8	$142.3	13.8%	4.5%	0.6%	$769.3
Idaho	$2.7	$7.3	$54.0	17.0%	6.1%	0.8%	$757.4
Delaware	$2.1	$6.8	$60.6	12.1%	3.7%	0.4%	$748.7
Montana	$1.7	$5.6	$36.0	16.4%	4.9%	0.8%	$737.6
New Hampshire	$2.5	$7.6	$59.4	14.4%	4.7%	0.6%	$706.2
Arkansas	$3.9	$14.5	$101.8	20.1%	5.4%	0.8%	$703.9
Ohio	$27.5	$67.8	$471.3	11.3%	4.6%	0.7%	$697.1
Kentucky	$7.9	$22.3	$156.6	14.4%	5.1%	0.7%	$685.1
Tennessee	$9.8	$34.8	$244.5	16.7%	4.7%	0.7%	$674.2
Georgia	$14.9	$49.6	$395.2	17.0%	5.1%	0.6%	$669.3
Vermont	$1.2	$4.3	$25.4	13.2%	3.7%	0.6%	$659.3
Maine	$2.1	$7.9	$51.3	16.1%	4.2%	0.6%	$655.0
Wisconsin	$12.3	$35.6	$244.4	11.4%	3.9%	0.6%	$641.3
South Dakota	$1.5	$4.3	$38.3	13.1%	4.7%	0.5%	$639.7
North Dakota	$1.2	$5.1	$31.9	12.8%	3.0%	0.5%	$627.8
Nebraska	$2.5	$14.4	$86.4	16.8%	2.9%	0.5%	$610.2
Pennsylvania	$21.5	$77.3	$554.8	13.1%	3.6%	0.5%	$579.9
Texas	$54.8	$129.1	$1,144.7	9.0%	3.8%	0.4%	$520.3
North Carolina	$18.7	$49.8	$398.0	9.5%	3.6%	0.4%	$495.0
Colorado	$7.9	$31.8	$252.7	11.3%	2.8%	0.4%	$462.8

Table 3: Service Costs as Percent of Payroll, State and Local Aggregated to State Level

	ABO Service Cost		EAN Service Cost		Actual Contributions		Cost / Contribution	
	Stated	Treasury	Stated	Treasury	Employee	Total	ABO	EAN
	(1)	(2)	(3)	(4)	(5)	(6)	(2)/(6)	(4)/(6)
Oregon	14.8%	30.4%	9.8%	28.5%	0.1%	8.4%	3.6	3.4
Wyoming	17.7%	30.3%	14.2%	29.2%	5.3%	10.3%	2.9	2.8
Delaware	15.4%	23.1%	13.0%	22.3%	2.4%	8.3%	2.8	2.7
North Dakota	17.7%	26.9%	14.7%	25.9%	4.7%	11.3%	2.4	2.3
Pennsylvania	18.2%	32.3%	14.6%	31.2%	7.0%	13.9%	2.3	2.2
North Carolina	16.6%	22.1%	14.6%	21.4%	6.2%	9.6%	2.3	2.2
Wisconsin	16.3%	25.9%	13.0%	24.7%	6.4%	11.6%	2.2	2.1
Minnesota	14.0%	26.5%	9.9%	25.1%	5.4%	11.9%	2.2	2.1
Vermont	14.5%	26.2%	11.1%	25.1%	4.8%	11.8%	2.2	2.1
Texas	18.2%	28.7%	15.0%	27.7%	6.0%	13.1%	2.2	2.1
Utah	18.3%	32.5%	14.1%	31.1%	0.9%	15.0%	2.2	2.1
New Jersey	15.1%	28.7%	10.8%	27.2%	6.2%	13.4%	2.1	2.0
Colorado	22.0%	40.8%	15.2%	38.5%	8.5%	19.8%	2.1	1.9
Washington	16.7%	26.5%	13.5%	25.5%	4.2%	12.9%	2.1	2.0
Kansas	14.5%	22.6%	12.0%	21.9%	4.1%	11.5%	2.0	1.9
Tennessee	16.3%	25.7%	12.8%	24.5%	3.1%	13.9%	1.8	1.8
New York	16.9%	30.4%	12.8%	29.1%	1.9%	16.6%	1.8	1.7
Nebraska	19.3%	32.4%	14.5%	30.8%	7.3%	17.9%	1.8	1.7
Iowa	14.9%	22.1%	12.4%	21.3%	4.6%	12.2%	1.8	1.7
South Dakota	15.9%	24.1%	12.8%	23.1%	6.5%	13.5%	1.8	1.7
Florida	15.3%	26.3%	11.9%	25.2%	1.4%	14.9%	1.8	1.7
New Hampshire	12.5%	23.7%	9.5%	22.8%	5.8%	14.0%	1.7	1.6
Georgia	18.5%	26.0%	15.8%	25.1%	4.5%	15.5%	1.7	1.6
New Mexico	23.0%	37.5%	17.9%	35.9%	9.0%	22.6%	1.7	1.6
Idaho	19.4%	28.3%	16.3%	27.4%	6.4%	17.1%	1.7	1.6
Kentucky	19.8%	28.1%	17.0%	27.2%	6.8%	17.5%	1.6	1.6
Ohio	21.2%	33.7%	16.7%	32.3%	10.2%	21.5%	1.6	1.5
California	20.4%	34.8%	15.3%	33.0%	7.8%	22.2%	1.6	1.5
Michigan	14.6%	24.0%	11.3%	22.9%	3.4%	15.3%	1.6	1.5
Missouri	19.9%	33.6%	15.4%	32.1%	7.1%	21.6%	1.6	1.5
Alaska	19.4%	33.5%	14.5%	31.9%	7.6%	22.1%	1.5	1.4
Montana	16.2%	28.6%	12.1%	27.2%	8.8%	19.0%	1.5	1.4
Virginia	16.3%	28.7%	12.6%	27.4%	0.8%	19.2%	1.5	1.4
Mississippi	20.0%	29.5%	16.3%	28.3%	7.4%	20.1%	1.5	1.4
Nevada	23.0%	36.4%	18.9%	35.2%	2.6%	25.0%	1.5	1.4
South Carolina	16.9%	25.7%	14.0%	24.8%	7.3%	18.2%	1.4	1.4
Connecticut	17.4%	26.0%	14.1%	25.0%	4.4%	19.0%	1.4	1.3
Alabama	18.3%	24.7%	15.8%	23.9%	5.6%	18.0%	1.4	1.3
Maryland	17.9%	25.8%	14.5%	24.7%	5.6%	18.9%	1.4	1.3
Oklahoma	18.3%	31.5%	14.3%	30.1%	6.8%	23.8%	1.3	1.3
Arizona	16.7%	22.8%	14.6%	22.2%	8.1%	17.4%	1.3	1.3
Hawaii	12.1%	22.6%	8.7%	21.4%	4.5%	17.4%	1.3	1.2
Louisiana	19.6%	34.0%	15.6%	32.8%	8.8%	26.3%	1.3	1.2
Arkansas	15.6%	24.1%	12.1%	22.9%	4.9%	18.7%	1.3	1.2
Maine	22.6%	30.1%	18.7%	28.8%	7.5%	23.5%	1.3	1.2
Rhode Island	21.4%	36.3%	16.8%	34.8%	8.7%	29.1%	1.2	1.2
Massachusetts	18.5%	32.7%	13.4%	31.3%	11.2%	26.6%	1.2	1.2
Illinois	18.4%	31.5%	14.0%	30.1%	8.4%	26.6%	1.2	1.1
West Virginia	18.0%	28.7%	14.8%	27.6%	7.7%	25.6%	1.1	1.1
Indiana	12.4%	16.6%	10.4%	16.0%	3.1%	17.2%	1.0	0.9
Overall	17.8%	29.5%	13.9%	28.2%	5.8%	17.7%	1.7	1.6

Table 4: Necessary Contributions and Contribution Increases for Full Funding in 30 Years without Policy Changes

		Total Required Contribution				Required Increase Above Current Rates			
		ABO, 10yr Average State GSP Growth		ABO, 10yr Average GSP Growth - 1%		ABO, 10yr Average State GSP Growth		ABO, 10yr Average GSP Growth - 1%	
Contributions / Payroll	Weighted Average	40.7%		42.7%		24.3%		26.4%	
	Mean, StDev	38.7%	7.0%	40.6%	7.7%	22.1%	6.9%	24.1%	7.5%
	Min, Max	24.7%	53.9%	25.1%	58.6%	7.5%	42.5%	8.8%	46.1%
	Min State, Max State	NC	CO	NC	IL	IN	CO	IN	CO
Contributions / Tax Revenue	Weighted Average	22.7%		23.9%		13.6%		14.7%	
	Mean, StDev	21.0%	5.5%	22.0%	5.9%	12.0%	4.4%	13.1%	4.8%
	Min, Max	12.2%	34.6%	12.9%	36.2%	3.6%	24.7%	4.2%	26.3%
	Min State, Max State	AK	OR	ND	OR	IN	OR	IN	OR
Contributions / Total Own Revenue	Weighted Average	14.2%		14.9%		8.5%		9.2%	
	Mean, StDev	12.7%	3.3%	13.4%	3.6%	7.3%	2.7%	7.9%	3.0%
	Min, Max	6.4%	20.2%	7.0%	22.3%	2.2%	13.4%	2.6%	14.7%
	Min State, Max State	AK	IL	AK	IL	IN	OH	IN	OH
Contributions / GSP	Weighted Average	2.0%		2.1%		1.2%		1.3%	
	Mean, StDev	1.8%	0.5%	1.9%	0.5%	1.0%	0.4%	1.1%	0.4%
	Min, Max	1.1%	3.0%	1.1%	3.2%	0.3%	1.9%	0.4%	2.1%
	Min State, Max State	DE	NM	DE	NM	IN	OH	IN	OH
Contributions / Household	Weighted Average	$2,339		$2,459		$1,398		$1,518	
	Mean, StDev	$2,111	$658	$2,217	$702	$1,219	$502	$1,325	$544
	Min, Max	$1,211	$3,989	$1,267	$4,157	$329	$2,475	$385	$2,677
	Min State, Max State	IN	NY	IN	NY	IN	NJ	IN	NJ

Table 5: Required Increases for Full Funding by State, No Policy Change

	Gvt Contributions		Required Contribution Increase				
	Current ($B)	Total Required ($B)	% of Payroll	% of Tax Revenue	% of Own Revenue	% of GSP	per household
New Jersey	$3.6	$11.9	30.9%	17.4%	12.7%	1.7%	$2,475
New York	$13.1	$30.0	25.7%	12.3%	8.6%	1.5%	$2,250
Oregon	$1.3	$4.4	36.1%	24.7%	13.2%	1.9%	$2,140
Wyoming	$0.2	$0.6	23.7%	10.3%	6.5%	1.2%	$2,080
Ohio	$3.1	$12.2	33.2%	21.3%	13.4%	1.9%	$2,051
California	$19.5	$47.8	26.2%	17.7%	10.8%	1.5%	$1,994
Minnesota	$1.7	$5.6	28.9%	16.9%	11.0%	1.5%	$1,928
Illinois	$6.0	$15.5	32.3%	17.8%	12.3%	1.5%	$1,907
New Mexico	$0.9	$2.3	29.1%	20.4%	11.4%	1.8%	$1,756
Colorado	$0.9	$4.3	42.5%	19.0%	10.6%	1.3%	$1,739
Rhode Island	$0.6	$1.3	27.0%	14.0%	9.4%	1.3%	$1,576
Pennsylvania	$2.8	$10.3	34.9%	14.8%	9.7%	1.4%	$1,550
Wisconsin	$1.4	$4.7	27.0%	14.2%	9.3%	1.4%	$1,522
Connecticut	$1.6	$3.6	22.1%	9.6%	7.5%	0.9%	$1,459
Michigan	$3.0	$8.3	31.7%	15.4%	9.3%	1.4%	$1,386
Washington	$2.5	$6.0	20.8%	13.5%	7.4%	1.0%	$1,371
Alaska	$0.3	$0.7	15.9%	6.4%	3.4%	0.8%	$1,356
Hawaii	$0.7	$1.4	17.2%	10.4%	6.9%	1.0%	$1,288
Texas	$5.0	$17.1	22.1%	15.4%	9.4%	1.1%	$1,271
Missouri	$1.8	$4.7	26.9%	15.5%	9.7%	1.2%	$1,264
Kentucky	$1.1	$3.2	26.4%	15.2%	9.4%	1.3%	$1,260
Delaware	$0.3	$0.7	19.5%	11.6%	6.1%	0.7%	$1,210
Kansas	$0.9	$2.2	19.2%	11.7%	7.1%	1.0%	$1,197
South Carolina	$1.5	$3.6	23.5%	17.7%	7.9%	1.3%	$1,186
Vermont	$0.2	$0.4	23.2%	9.6%	6.5%	1.1%	$1,163
Mississippi	$1.1	$2.4	21.8%	14.5%	8.2%	1.3%	$1,127
Louisiana	$1.5	$3.5	21.9%	11.8%	7.3%	0.9%	$1,118
Virginia	$4.2	$7.4	18.5%	11.1%	6.8%	0.8%	$1,066
Massachusetts	$2.2	$4.9	19.9%	8.8%	5.7%	0.7%	$1,057
North Dakota	$0.2	$0.4	21.3%	7.8%	5.0%	0.8%	$1,042
New Hampshire	$0.4	$0.9	20.6%	11.0%	6.8%	0.9%	$1,010
Nevada	$1.2	$2.1	17.2%	9.3%	5.9%	0.7%	$884
Nebraska	$0.4	$1.0	24.3%	8.6%	4.2%	0.7%	$881
Montana	$0.3	$0.6	19.4%	9.7%	5.8%	0.9%	$872
Alabama	$1.9	$3.5	15.4%	12.2%	6.1%	0.9%	$868
Iowa	$0.9	$1.9	15.4%	8.5%	5.0%	0.7%	$861
Oklahoma	$1.4	$2.7	19.3%	10.0%	5.9%	0.8%	$850
Tennessee	$1.6	$3.7	20.8%	11.8%	5.8%	0.8%	$837
Maryland	$2.2	$4.0	15.6%	6.7%	4.9%	0.6%	$818
Florida	$5.5	$11.3	20.3%	8.9%	5.3%	0.8%	$813
Georgia	$2.5	$5.6	20.4%	10.1%	6.1%	0.8%	$803
North Carolina	$1.8	$4.6	15.1%	9.5%	5.7%	0.7%	$784
South Dakota	$0.2	$0.4	15.9%	9.6%	5.7%	0.6%	$776
Maine	$0.3	$0.7	18.7%	7.1%	4.9%	0.8%	$761
Idaho	$0.5	$0.9	16.5%	10.2%	6.0%	0.8%	$737
Arizona	$2.0	$3.6	11.6%	7.8%	4.7%	0.6%	$608
West Virginia	$0.7	$1.1	14.7%	6.7%	4.1%	0.7%	$600
Utah	$0.9	$1.5	13.2%	6.9%	3.6%	0.5%	$538
Arkansas	$0.8	$1.4	15.2%	6.4%	4.1%	0.6%	$534
Indiana	$2.2	$3.0	7.5%	3.6%	2.2%	0.3%	$329

Table 6: Effects of Limits on Debt Issuance

This table accounts for variation in municipal indebtedness that affect the ability of governments to issue debt to fund pension liabilities. These effects are modeled as reductions in pension fund assets to reflect the difference between a state's aggregate municipal debt relative to GSP and the ratio of aggregate national municipal debt to national GDP. If a state's aggregate municipal debt relative to GSP exceeds aggregate national municipal debt relative to national GDP, its pension fund assets are reduced to reflect the difference. Conversely, if a state's debt is relatively small relative to its economy, the difference is added to its pension fund assets. See Section III.E for details.

	State and Local Debt		Effect of Debt Restriction on Required Annual Contribution	
	$ billions	% of GSP	as % of GSP	% of own revenue
5 States with Largest Effects of Debt Restrictions				
Kentucky	42.0	27%	0.30%	2.13%
Massachusetts	96.3	26%	0.26%	2.05%
New York	289.6	26%	0.26%	1.43%
Rhode Island	11.7	25%	0.18%	1.29%
South Carolina	36.8	23%	0.15%	0.91%
5 States Most Able to Take Advantage of Debt				
North Dakota	3.3	10%	-0.20%	-1.22%
Georgia	52.0	13%	-0.20%	-1.58%
Arkansas	12.5	12%	-0.20%	-1.43%
Idaho	5.9	11%	-0.22%	-1.60%
Iowa	13.6	10%	-0.27%	-1.91%

Table 7: Necessary Contribution Increases, No Tiebout Effect, Soft and Hard Freeze

		ABO, 10yr Average State GSP Growth		ABO, 10yr Average GSP Growth - 1%		ABO, 10yr Average U.S. GSP Growth	
Panel A: Soft Freeze							
Δ[Contributions / Payroll]	Weighted Average	21.3%		24.4%		20.8%	
	Mean, StDev	18.3%	8.9%	21.2%	10.0%	18.7%	8.1%
	Min, Max	6.2%	47.8%	7.9%	53.9%	4.9%	51.6%
		IN	CO	IN	CO	IN	CO
Δ[Contributions / Tax Revenue]	Weighted Average	11.9%		13.6%		11.6%	
	Mean, StDev	9.9%	5.2%	11.5%	5.9%	10.1%	4.7%
	Min, Max	3.0%	26.4%	3.7%	29.3%	2.3%	23.0%
		IN	OH	IN	OH	IN	CO
Δ[Contributions / Own Revenue]	Weighted Average	7.4%		8.5%		7.3%	
	Mean, StDev	6.1%	3.3%	7.0%	3.7%	6.1%	2.9%
	Min, Max	1.8%	16.6%	2.3%	18.5%	1.4%	13.9%
		IN	OH	IN	OH	IN	OH
Δ[Contributions / GSP]	Weighted Average	1.0%		1.2%		1.0%	
	Mean, StDev	0.9%	0.4%	1.0%	0.5%	0.9%	0.4%
	Min, Max	0.3%	2.4%	0.3%	2.7%	0.2%	2.0%
		IN	OH	IN	OH	IN	OH
Δ[Contributions / Household]	Weighted Average	$1,223		$1,406		$1,199	
	Mean, StDev	$1,007	$551	$1,163	$622	$1,033	$526
	Min, Max	$272	$2,540	$343	$2,820	$214	$2,215
		IN	OH	IN	OH	IN	NJ
Panel B: Hard Freeze							
Δ[Contributions / Payroll]	Weighted Average	14.0%		16.0%		13.6%	
	Mean, StDev	12.2%	6.9%	14.0%	7.5%	12.3%	6.1%
	Min, Max	2.1%	32.6%	3.7%	36.2%	3.0%	34.9%
		VA	CO	VA	CO	IN	CO
Δ[Contributions / Tax Revenue]	Weighted Average	7.8%		8.9%		7.6%	
	Mean, StDev	6.6%	4.0%	7.6%	4.3%	6.6%	3.5%
	Min, Max	1.3%	20.5%	2.2%	22.6%	1.4%	17.5%
		VA	OH	VA	OH	IN	OH
Δ[Contributions / Own Revenue]	Weighted Average	4.9%		5.6%		4.7%	
	Mean, StDev	4.1%	2.5%	4.7%	2.7%	4.1%	2.2%
	Min, Max	0.8%	13.0%	1.3%	14.2%	0.9%	11.0%
		VA	OH	VA	OH	IN	OH
Δ[Contributions / GSP]	Weighted Average	0.7%		0.8%		0.7%	
	Mean, StDev	0.6%	0.3%	0.7%	0.4%	0.6%	0.3%
	Min, Max	0.1%	1.9%	0.2%	2.0%	0.1%	1.6%
		VA	OH	VA	OH	IN	OH
Δ[Contributions / Household]	Weighted Average	$805		$920		$784	
	Mean, StDev	$668	$399	$768	$438	$679	$368
	Min, Max	$124	$1,980	$211	$2,175	$131	$1,687
		VA	OH	VA	OH	IN	OH

Appendix

Calculating a plan's liability cash flows

A plan's total liability cash flow *t* years in the future, recognized under the accounting methodology $m \in \{abo, pbo, ean, pvb\}$, comes from its promises to current workers, current annuitants, and separated workers not yet receiving benefits,

$$\tilde{B}_t^m = \tilde{B}_t^{active,m} + \tilde{B}_t^{retired} + \tilde{B}_t^{separated}.$$

A plan's total liability *t* years in the future due to its promises to its current workers is given by

$$\tilde{B}_t^{active,m} = \sum_{a=R_1-t+1}^{R_F} \sum_{s=1}^{a-a_{\min}+1} \sum_{r=0}^{t-1} N_{a,s}\mu_{a,a+r}S_{a,a+t}b_{a,s,r,t}^m$$

where R_1 is the first age at which workers can start taking benefits (typically assumed to be 55), R_F is the age of forced retirement (typically assumed to be 75), $a_{\min}$ is the age of the youngest workers typically assumed to be 21), $N_{a,s}$ is the number of workers of age *a* with *s* years of service, $\mu_{a,a+r}$ is the fraction of workers of age *a* separating in *r* years, $S_{a,a+t}$ is the fraction of workers of age *a* surviving to age *a* + *t* (gender specific, and accounting for survivor benefits when applicable), and $b_{a,s,r,t}^m$ is the average benefit payment *t* years in the future recognized under the accounting methodology *m* to a worker of age *a* with *s* years of service that separates in *r* years.

The benefit payments recognized under the ABO this is given by

$$b_{a,s,r,t}^{abo} = \mathbf{1}_{s\geq v}\lambda_{a+r}s\alpha_f w_{a,s}\left(1+COLA\right)^{t-\max\{r,R_1-a\}}$$

where $\mathbf{1}_{s\geq v}$ is an indicator variable that accounts for the *v* year vesting period (typically assumed to be five years), $\lambda_{a+r} = 1 - BOR \times \min\left\{R_2 - R_1, \max\left\{R_2 - \left(a+r\right), 0\right\}\right\}$ and reflects the reduction in benefits (*BOR*, typically assumed to be 6%/year) made to workers that start taking benefits before the age of full retirement (R_2 , typically assumed to be 60), under the assumption that separated workers begin taking retirement benefits as soon as they are eligible to do so because the buyout rate schedules employed by state and local retirement plans makes early retirement actuarially favorable to workers, α_f is the benefit factor, and $w_{a,s}$ is the average salary of a worker of age *a* with *s* years of service, and the last factor accounts for the fact that the COLAs only apply after a worker starts taking benefits, which happens after separation or when a worker reaches age R_1, whichever comes later.

The benefit payments recognized under the other accounting methodologies are given by

$$b_{a,s,r,t}^{m} = \phi_{a,s,r}^{m} \mathbf{1}_{s+r \geq v} \lambda_{a+r} \left(s+r\right) \alpha_f \left(\prod_{i=1}^{r} \left(1+g_{a+i}\right) \right) w_{a,s} \left(1+COLA\right)^{t-\max\{r, R_1 - a\}}$$

where g_a is the rate of wage growth for a worker of age *a*, and $\phi_{a,s,r}^{m}$ is the fraction of total benefit payments to a worker of age *a* with *s* years of service separating in *r* years recognized under the accounting methodology *m*. For the PVB, which fully recognizes benefit payments, $\phi_{a,s,r}^{pvb} = 1$; for the PBO, which recognizes the benefit payments in proportion to the fraction of lifetime service performed to date, $\phi_{a,s,r}^{pbo} = \frac{s}{s+r}$; and for the EAN, which recognizes the benefit payments in proportion to the fraction of discounted lifetime wages earned to date,

$$\phi_{a,s,r}^{ean} = \frac{\sum_{i=1}^{s} S_{a-s,a-s+i} \left(1+r_d\right)^{-i} \prod_{j=1}^{i-1} \left(1+g_{a-s+j}\right)}{\sum_{i=1}^{s+r} S_{a-s,a-s+i} \left(1+r_d\right)^{-i} \prod_{j=1}^{i-1} \left(1+g_{a-s+j}\right)}$$

where r_d is the rate used to discount cash flows.

A plan's total liability *t* years in the future due to its promises to its current annuitants is given by

$$\tilde{B}_t^{retired} = \sum_{a=a_{\min}^{A}}^{a_{\max}^{A}} N_a^A S_{a,a+t} A_a \left(1+COLA\right)^t$$

where $a_{\min}^{A}$ and $a_{\max}^{A}$ are the minimum and maximum age of current annuitants (typically assumed to be 45 and 95, respectively), N_a^A is the number of annuitants of age *a*, and A_a if the average benefit annual benefit payment to annuitants of age *a*.

A plan's total liability *t* years in the future due to separated vested workers not yet receiving benefits is given by

$$\tilde{B}_t^{separated} = \sum_{s=v}^{s_{\max}} \sum_{a=a_{\min}+s}^{R_1} N_{a,s}^S S_{a,a+t} \lambda_0 s b_f w_{a,s}^S \left(1+COLA\right)^{t-(R_1-a)}$$

where $N_{a,s}^S$ is the number of separated vested workers not yet receiving benefits of age *a* with service *s*, and $w_{a,s}^S$ is these workers' average benefits eligible salary.

Total liability cash flows are calibrated to a plan's stated liability using a geometric series

$$B_t^m = \left(1+\lambda\right)^{t-1} \tilde{B}_t^m,$$

where λ is picked such that the calibrated cash flows, recognized under the accounting methodology employed by the state and discount at the state chosen discount rate, yields the plans stated liability. That is, λ is chosen to satisfy

$$\sum_{t=1}^{\infty} \frac{\left(1+\lambda\right)^{t-1} \tilde{B}_t^{m_{stated}}}{\left(1+r_{stated}\right)^t} = L_{stated}$$

where m_{stated}, r_{stated} and L_{stated} are the plan's stated accounting methodology, discount rate and liability, respectively.

Normal costs

In order to calculate the cost of new benefit accruals, or normal cost, we first determine the expected one year change in the benefit payments recognized under each accounting methodology

$$\Delta\tilde{B}_t^{active,m} = \left(\sum_{a=R_1-t+1}^{R_F} \sum_{s=1}^{a-a_{\min}+1} \sum_{r=1}^{t-1} N_{a,s} \mu_{a,a+r} S_{a,a+t} \Delta b_{a,s,r,t}^m \right) + \tilde{B}_t^{new\_hires,m}$$

where

$$\Delta b_{a,s,r,t}^m = \omega_{a,s} b_{a+1,s+1,r-1,t-1}^m - b_{a,s,r,t}^m$$

and we assume that either wages for workers of a given age and tenure grow at the rate of inflation $\omega_{a,s} = 1+i$ where *i* is the plan's inflation rate assumption, or that wages for workers of age a grow at the rate g_a so that $\omega_{a,s} = (1+g_a) w_{a,s} / w_{a+1,s+1}$, and

$$\tilde{B}_t^{new\_hires,m} = \sum_{a=R_1-t+1}^{R_F} \sum_{r=0}^{t-1} N_a^{new\_hires} \mu_{a,a+r} S_{a,a+t} (1+i) b_{a,1,r,t}^m$$

where we assume that new workers with no previous service are hired to replace those that retire, and that new hires have the same age distribution as current workers in their first year of service,

$$N_a^{new\_hires} = N_{a,1} \left(\sum_{a'=a_{\min}}^{R_F} \sum_{s=1}^{a'-a_{\min}+1} N_{a',s} \mu_{a',a'} \right) / \left(\sum_{a'=a_{\min}}^{R_F} N_{a',1} \right).$$

We calibrate the change in the benefit payments using the same adjustment factor used to calibrate the currently recognized benefits, $\Delta B_t^{active,m} = (1-\lambda)^{t-1} \Delta\tilde{B}_t^{active,m}$. The normal cost if the present value in the increase in the calibrated recognized benefits,

$$NC^m = \sum_{t=2}^{\infty} (1-r_t)^{-t} \Delta B_t^{active,m}$$

where r_t is the discount rate used to discount year *t* cash flows.

Harmonizing Inflation Rate Assumptions

Each plan's liability cash flows, as well as the expected cost of new benefit accruals, are reforecast under a uniform inflation assumption. This is done using the methodology described above, with two important modifications. First, we reduce the wage growth assumption for workers of every age by 1.36%/year, the difference between the liability-weighted average plan inflation assumption and the Cleveland Fed's forecast of 2%/year. Second, we reduce the COLA applicable to post retirement benefit payments by the difference between the plan specific inflation rate assumption and the Cleveland Fed's forecast. We calibrate these cash flows using the geometric series retained from the calculations employing the plan specific inflation assumptions.

Contributions to Pension Systems

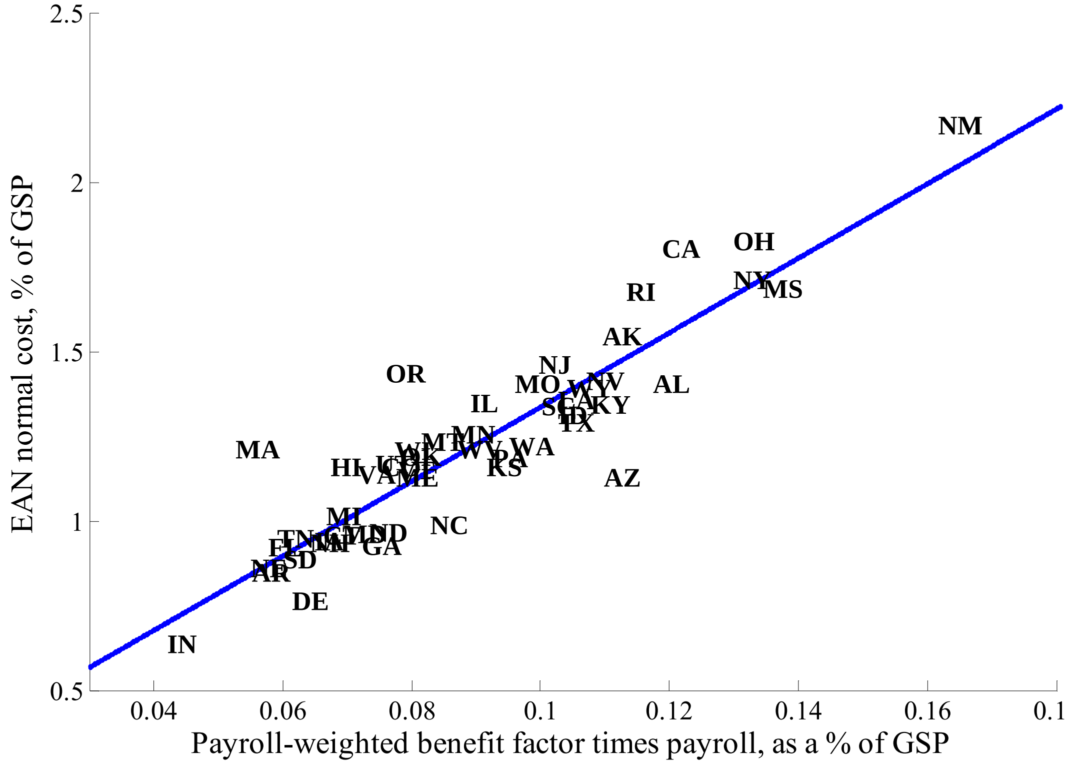
The study requires measures of contributions to state and local pension systems from both employees and governments. U.S. Census Bureau (2010a) contains data on total pension contributions to each level of government, decomposed into government contributions and employee contributions. For example, the data show that in California in 2008 there were $6.04 billion in employee contributions to state-sponsored plans, $11.37 billion in government contributions to state-sponsored plans, $1.75 billion in employee contributions to locally-sponsored plans, and $4.39 billion in government contributions to locally-sponsored plans.

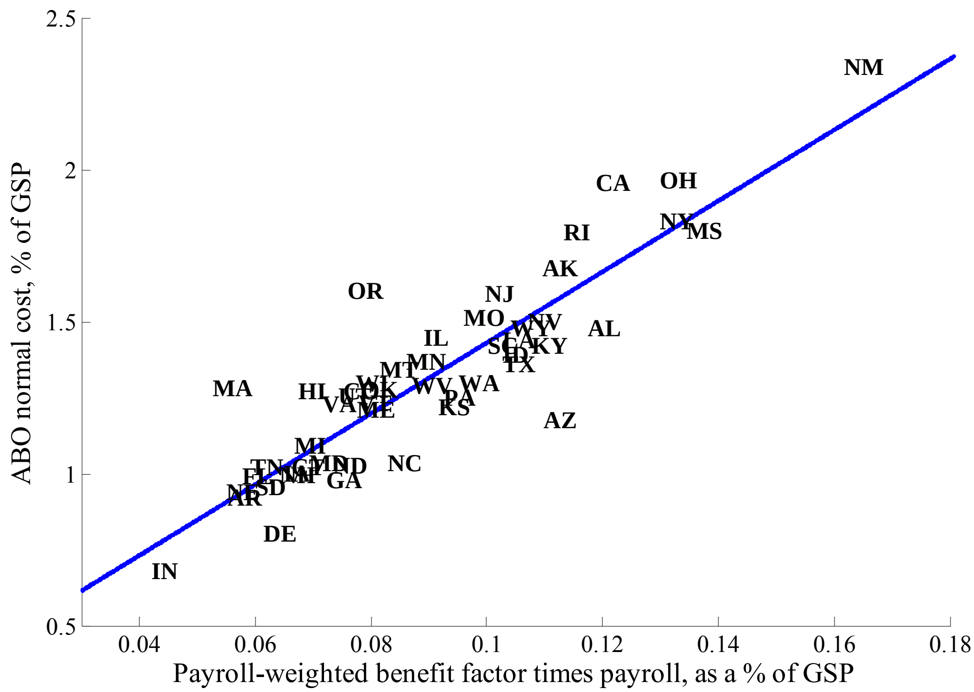
Using calculations on contribution growth rates from Novy-Marx and Rauh (2011a), we estimate 2009 contributions based on the growth rate of employee and government contributions in the state plans covered by that study. For example, for California Novy-Marx and Rauh (2011a) found that between 2008 and 2009, employee contributions grew by 7.2% for the funds covered in that study (CalPERS, CalSTRS, and the University of California Retirement Plan), while government contributions shrank by 3.4%, so that total contributions shrank by 0.1%.[22] Applying these growth rates to both the state and local cells for California, we estimate that in California in 2009, there were $6.47 billion of employee contributions to state-sponsored plans, $10.95 billion of government contributions to state-sponsored plans, $1.87 billion of employee contributions to locally-sponsored plans, and $4.28 billion of government contributions to locally-sponsored plans. The total government contributions were therefore $15.23 billion (= $10.95 + $4.28) and the total employee contributions were $8.34 billion (=$6.47 + $1.87). These are estimates of total contributions to all DB pension systems sponsored by government entities in the state of California.

When looking at contribution measures in systems that include Social Security, we add 6.2% of payroll to employer (and employee) contributions. For example, given the share of workers in California systems that are in Social Security, we estimate total government contributions including Social Security at $19.46 billion in 2009, as opposed to $15.23 billion excluding Social Security.

[22] Employer contributions to CalPERS shrank from $7.2 billion in 2008 to $6.9 billion in 2009.

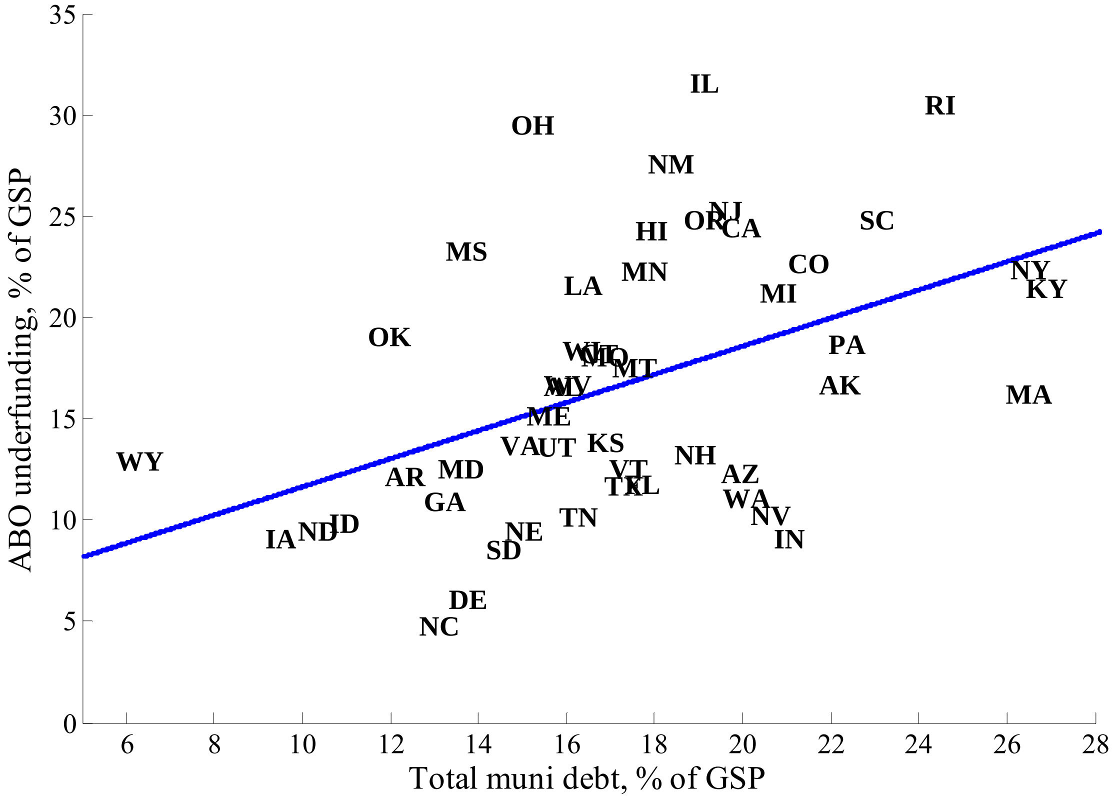
Appendix Figure 1: Service Cost as a Percent of Payroll and Benefit Factors





Appendix Figure 2: Pension Debt and Non-Pension Debt are Complements

The horizontal axis is total municipal debt as recognized in the U.S. Census of Governments, as a percentage of GSP. The vertical axis is the gap between assets and the present value of liabilities on an ABO basis. Each additional dollar in municipal debt is associated with an additional 67 cents in ABO pension underfunding, and this relation has a t-statistic of 3.61.



Appendix Table 1: Necessary Contributions and Contribution Increases for Full Funding in 30 Years without Policy Changes Under Alternative Assumptions

		Total Required Contribution				Required Increase Above Current Rates			
		ABO, 10yr Average U.S. GSP Growth		EAN, 10yr Average GSP Growth		ABO, 10yr Average U.S. GSP Growth		EAN, 10yr Average GSP Growth	
Contributions / Payroll	Weighted Average	40.3%		43.5%		23.9%		27.1%	
	Mean, StDev	38.9%	6.5%	41.4%	7.4%	22.1%	6.9%	24.1%	7.5%
	Min, Max	24.6%	56.1%	26.1%	59.3%	7.5%	42.5%	8.8%	46.1%
	Min State, Max State	NC	CO	NC	CO	IN	CO	IN	CO
Contributions / Tax Revenue	Weighted Average	22.5%		24.3%		13.3%		15.1%	
	Mean, StDev	21.0%	5.3%	22.4%	5.9%	12.0%	4.4%	13.1%	4.8%
	Min, Max	12.7%	35.2%	13.6%	37.6%	3.6%	24.7%	4.2%	26.3%
	Min State, Max State	IN	OR	ND	OR	IN	OR	IN	OR
Contributions / Total Own Revenue	Weighted Average	14.0%		15.1%		8.3%		9.4%	
	Mean, StDev	12.8%	3.1%	13.6%	3.5%	7.3%	2.7%	7.9%	3.0%
	Min, Max	7.3%	19.2%	7.5%	21.3%	2.2%	13.4%	2.6%	14.7%
	Min State, Max State	NE	NM	AK	IL	IN	OH	IN	OH
Contributions / GSP	Weighted Average	1.9%		2.1%		1.2%		1.3%	
	Mean, StDev	1.8%	0.5%	1.9%	0.5%	1.0%	0.4%	1.1%	0.4%
	Min, Max	1.1%	3.1%	1.2%	3.3%	0.3%	1.9%	0.4%	2.1%
	Min State, Max State	IN	NM	DE	NM	IN	OH	IN	OH
Contributions / Household	Weighted Average	$2,317		$2,502		$1,376		$1,561	
	Mean, StDev	$2,128	$670	$2,265	$713	$1,219	$502	$1,325	$544
	Min, Max	$1,165	$3,949	$1,268	$4,242	$329	$2,475	$385	$2,677
	Min State, Max State	IN	NY	IN	NY	IN	NJ	IN	NJ

Appendix Table 2: Contribution Increases Including Tiebout Effect, No Policy Changes

		ABO, 10yr Average GSP Growth		ABO, 10yr Average GSP Growth - 1%		ABO, 10yr Average National GSP Growth		EAN, 10yr Average GSP Growth	
Δ[Contributions / Payroll]	Weighted Average	25.2%		27.7%		24.5%		28.0%	
	Mean, Standard Dev	22.1%	8.7%	24.0%	10.1%	22.2%	7.8%	24.9%	8.7%
	Min, Max	5.4%	43.5%	6.2%	52.4%	4.6%	46.9%	7.0%	48.9%
	Min State, Max State	IN	CO	IN	IL	IN	CO	IN	CO
Δ[Contributions / Tax Revenue]	Weighted Average	14.1%		15.5%		13.7%		15.6%	
	Mean, Standard Dev	12.1%	5.6%	13.2%	6.4%	12.1%	5.0%	13.6%	5.6%
	Min, Max	2.6%	27.7%	3.0%	29.9%	2.2%	29.0%	3.3%	30.2%
	Min State, Max State	IN	OR	IN	OH	IN	OR	IN	OR
Δ[Contributions / Own Revenue]	Weighted Average	8.8%		9.7%		8.5%		9.7%	
	Mean, Standard Dev	7.3%	3.4%	8.0%	4.0%	7.3%	3.0%	8.3%	3.5%
	Min, Max	1.6%	16.6%	1.8%	20.0%	1.3%	15.6%	2.0%	17.2%
	Min State, Max State	IN	OH	IN	IL	IN	OR	IN	OH
Δ[Contributions / GSP]	Weighted Average	1.2%		1.3%		1.2%		1.3%	
	Mean, Standard Dev	1.0%	0.5%	1.1%	0.6%	1.0%	0.4%	1.2%	0.5%
	Min, Max	0.2%	2.4%	0.3%	2.7%	0.2%	2.2%	0.3%	2.5%
	Min State, Max State	IN	OH	IN	OH	IN	OR	IN	OH
Δ[Contributions / Household]	Weighted Average	$1,452		$1,596		$1,411		$1,609	
	Mean, Standard Dev	$1,225	$609	$1,336	$694	$1,239	$588	$1,382	$635
	Min, Max	$236	$2,763	$272	$3,091	$200	$2,680	$306	$2,966
	Min State, Max State	IN	NJ	IN	IL	IN	NJ	IN	NJ

Appendix Table 3: Required Contribution Increases, 2% Tiebout Effect, No Policy Change

	Gvt Contributions		Required Contribution Increase				
	Current ($B)	Required ($B)	% of Payroll	% of Tax Revenue	% of Own Revenue	% of GSP	per household
New Jersey	$3.6	$12.9	34.4%	19.5%	14.1%	1.9%	$2,763.1
Ohio	$3.1	$14.4	41.1%	26.4%	16.6%	2.4%	$2,541.4
Oregon	$1.3	$4.8	40.6%	27.7%	14.9%	2.1%	$2,408.8
New York	$13.1	$31.1	27.3%	13.1%	9.1%	1.6%	$2,393.2
Illinois	$6.0	$17.5	39.2%	21.6%	15.0%	1.8%	$2,313.0
California	$19.5	$49.5	27.8%	18.8%	11.5%	1.6%	$2,115.9
Wyoming	$0.2	$0.6	23.6%	10.2%	6.5%	1.2%	$2,072.4
Minnesota	$1.7	$5.8	30.6%	17.8%	11.6%	1.6%	$2,040.2
New Mexico	$0.9	$2.5	33.2%	23.3%	13.1%	2.1%	$2,004.3
Colorado	$0.9	$4.3	43.5%	19.4%	10.8%	1.4%	$1,780.1
Rhode Island	$0.6	$1.3	28.1%	14.5%	9.8%	1.4%	$1,638.0
Pennsylvania	$2.8	$10.5	35.8%	15.2%	10.0%	1.4%	$1,588.8
Wisconsin	$1.4	$4.8	27.6%	14.6%	9.5%	1.4%	$1,559.1
Michigan	$3.0	$8.7	33.7%	16.4%	10.0%	1.5%	$1,476.2
Washington	$2.5	$5.9	20.3%	13.2%	7.3%	1.0%	$1,343.7
Connecticut	$1.6	$3.4	20.2%	8.8%	6.9%	0.8%	$1,336.2
Kentucky	$1.1	$3.3	27.1%	15.7%	9.6%	1.4%	$1,295.7
Missouri	$1.8	$4.7	26.9%	15.5%	9.7%	1.2%	$1,263.4
Texas	$5.0	$16.9	21.7%	15.1%	9.2%	1.0%	$1,250.5
South Carolina	$1.5	$3.6	24.1%	18.1%	8.1%	1.3%	$1,215.7
Hawaii	$0.7	$1.3	16.0%	9.7%	6.4%	0.9%	$1,200.7
Kansas	$0.9	$2.2	18.7%	11.4%	6.9%	1.0%	$1,166.1
Delaware	$0.3	$0.7	18.7%	11.1%	5.8%	0.7%	$1,161.5
Mississippi	$1.1	$2.4	22.4%	14.9%	8.4%	1.4%	$1,157.8
Alaska	$0.3	$0.6	13.6%	5.4%	2.9%	0.7%	$1,154.0
Vermont	$0.2	$0.4	22.9%	9.5%	6.4%	1.1%	$1,143.8
Louisiana	$1.5	$3.3	20.4%	11.0%	6.8%	0.9%	$1,040.2
North Dakota	$0.2	$0.4	20.5%	7.5%	4.9%	0.8%	$1,005.0
Virginia	$4.2	$7.2	17.2%	10.4%	6.3%	0.7%	$991.3
New Hampshire	$0.4	$0.8	19.3%	10.3%	6.3%	0.8%	$947.5
Massachusetts	$2.2	$4.6	17.8%	7.8%	5.1%	0.7%	$945.7
Nevada	$1.2	$2.0	16.3%	8.8%	5.5%	0.7%	$834.3
Montana	$0.3	$0.6	18.3%	9.1%	5.5%	0.9%	$824.0
Nebraska	$0.4	$1.0	22.7%	8.0%	4.0%	0.7%	$823.7
Alabama	$1.9	$3.4	14.5%	11.5%	5.8%	0.9%	$817.2
Iowa	$0.9	$1.8	14.5%	8.0%	4.7%	0.7%	$810.4
Tennessee	$1.6	$3.6	19.7%	11.2%	5.5%	0.8%	$792.2
Oklahoma	$1.4	$2.5	17.5%	9.1%	5.3%	0.7%	$771.1
Florida	$5.5	$11.0	19.1%	8.3%	5.0%	0.7%	$764.9
North Carolina	$1.8	$4.5	14.7%	9.2%	5.5%	0.7%	$763.8
Georgia	$2.5	$5.4	19.0%	9.4%	5.7%	0.7%	$747.0
Maryland	$2.2	$3.8	13.9%	6.0%	4.3%	0.6%	$730.3
South Dakota	$0.2	$0.4	15.0%	9.0%	5.3%	0.6%	$728.7
Idaho	$0.5	$0.9	15.8%	9.8%	5.7%	0.8%	$706.1
Maine	$0.3	$0.7	16.8%	6.3%	4.4%	0.7%	$684.7
Arizona	$2.0	$3.4	10.4%	6.9%	4.2%	0.5%	$542.9
West Virginia	$0.7	$1.0	12.6%	5.7%	3.5%	0.6%	$512.0
Arkansas	$0.8	$1.3	13.2%	5.5%	3.5%	0.5%	$463.8
Utah	$0.9	$1.3	8.8%	4.6%	2.4%	0.3%	$360.2
Indiana	$2.2	$2.8	5.4%	2.6%	1.6%	0.2%	$236.2