pension_data_analysis

January 25, 2026

[1]:
```
import pandas as pd
import matplotlib.pyplot as plt
import geopandas as gpd
import seaborn as sns
```

1 Public Pension Risk in the US

1.1 Data

The data used for this report is from the new Public Plans Database (PPD) constructed by the Center for Retirement Research at Boston College, the U.S. Census Bureau, the NCSL, and the Current Population Survey (CPS). It contains the data since 2001 for 95% of the public sector members. ## Question to answer How do macroeconomic shocks and public health shocks differentially affect the funding position of U.S. public pension plans, and through which actuarial channels (assets, liabilities, and contributions) do these effects operate?

[32]:
```
pension_df = pd.read_csv("pension_data.csv", encoding="cp1252")
pension_df = pension_df[pension_df["fy"] > 2000]
pd.set_option("display.max_columns", None)
pension_df.head()
```

```
/var/folders/tr/w9p9c_hx39j1vrtknn93nc0c0000gn/T/ipykernel_88999/4151004807.py:1
: DtypeWarning: Columns (5) have mixed types. Specify dtype option on import or
set low_memory=False.
  pension_df = pd.read_csv("pension_data.csv", encoding="cp1252")
```

[32]:

	ppd_id	PlanName	fy	system_id	\
0	1	Alabama ERS	2001.0	1.0	
1	1	Alabama ERS	2002.0	1.0	
2	1	Alabama ERS	2003.0	1.0	
3	1	Alabama ERS	2004.0	1.0	
4	1	Alabama ERS	2005.0	1.0	

	PlanFullName	source_PlanBasics	FiscalYearType	\
0	Employees' Retirement System of Alabama	NaN	0.0	
1	Employees' Retirement System of Alabama	NaN	0.0	
2	Employees' Retirement System of Alabama	NaN	0.0	
3	Employees' Retirement System of Alabama	NaN	0.0	

```
4  Employees' Retirement System of Alabama               NaN             0.0

   PlanInceptionYear  PlanClosed  PlanYearClosed  AdministeringGovt  \
0             1945.0         0.0             NaN                0.0
1             1945.0         0.0             NaN                0.0
2             1945.0         0.0             NaN                0.0
3             1945.0         0.0             NaN                0.0
4             1945.0         0.0             NaN                0.0

  StateAbbrev StateName GovtName  PlanType  \
0          AL   Alabama  Alabama         1
1          AL   Alabama  Alabama         1
2          AL   Alabama  Alabama         1
3          AL   Alabama  Alabama         1
4          AL   Alabama  Alabama         1

                    EmployeeTypeCovered  SocSecCovered  \
0  Plan covers state and local employees            1.0
1  Plan covers state and local employees            1.0
2  Plan covers state and local employees            1.0
3  Plan covers state and local employees            1.0
4  Plan covers state and local employees            1.0

                   SocSecCovered_verbatim                  CostStructure  \
0  Plan members covered by Social Security  Multiple employer, agent plan
1  Plan members covered by Social Security  Multiple employer, agent plan
2  Plan members covered by Social Security  Multiple employer, agent plan
3  Plan members covered by Social Security  Multiple employer, agent plan
4  Plan members covered by Social Security  Multiple employer, agent plan

   EmployerType  CostSharing  \
0           2.0          0.0
1           2.0          0.0
2           2.0          0.0
3           2.0          0.0
4           2.0          0.0

                                    BenefitsWebsite  EEGroupID  TierID  \
0  https://www.rsa-al.gov/ers/planning-for-retire…        0.0     NaN
1  https://www.rsa-al.gov/ers/planning-for-retire…        0.0     NaN
2  https://www.rsa-al.gov/ers/planning-for-retire…        0.0     NaN
3  https://www.rsa-al.gov/ers/planning-for-retire…        0.0     NaN
4  https://www.rsa-al.gov/ers/planning-for-retire…        0.0     0.0

   ActRptDate         fye  ActCostMeth_GASB  \
0  2001-09-30  2001-09-30               0.0
1  2002-09-30  2002-09-30               0.0
```

```
2  2003-09-30  2003-09-30              0.0
3  2004-09-30  2004-09-30              0.0
4  2005-09-30  2005-09-30              0.0

                     AssetValMeth_GASB  FundingMeth_GASB  \
0  5-year smoothed market related value.               0.0
1  5-year smoothed market related value.               0.0
2  5-year smoothed market related value.               0.0
3  5-year smoothed market related value.               0.0
4  5-year smoothed market related value.               0.0

   InflationAssumption_GASB  InvestmentReturnAssumption_GASB  \
0                     0.045                             0.08
1                     0.045                             0.08
2                     0.045                             0.08
3                     0.045                             0.08
4                     0.045                             0.08

   ActCostMethCode_GASB  AssetValMethCode_GASB  AssetSmoothingPeriod_GASB  \
0                   1.0                    0.0                        5.0
1                   1.0                    0.0                        5.0
2                   1.0                    0.0                        5.0
3                   1.0                    0.0                        5.0
4                   1.0                    0.0                        5.0

   FundingMethCode1_GASB  FundingMethCode2_GASB  UAALAmortPeriod_GASB  \
0                    1.0                    1.0                  12.0
1                    1.0                    1.0                  18.0
2                    1.0                    1.0                  19.0
3                    1.0                    1.0                  19.0
4                    1.0                    1.0                  20.0

   BlendedDiscountRate AssetValMeth  PhaseIn AssetValMeth_note  ActCostMeth  \
0                  NaN          NaN      NaN               NaN          0.0
1                  NaN          NaN      NaN               NaN          0.0
2                  NaN          NaN      NaN               NaN          0.0
3                  NaN          NaN      NaN               NaN          0.0
4                  NaN          NaN      NaN               NaN          0.0

   ActCostMeth_note  FundingMeth  FundingMeth_note  MktAssets_Smooth  \
0               NaN          0.0               NaN               NaN
1               NaN          0.0               NaN               NaN
2               NaN          0.0               NaN               NaN
3               NaN          0.0               NaN               NaN
4               NaN          0.0               NaN               NaN

   ActAssets_Smooth  NetFlows_smooth  AssetValMethCode  SmoothingReset  \
```

```
0               NaN              NaN               NaN             NaN
1               NaN              NaN               NaN             NaN
2               NaN              NaN               NaN             NaN
3               NaN              NaN               NaN             NaN
4               NaN              NaN               NaN             NaN

   GainlossConcept  GainLossBase_1  GainLossBase_2  GainLoss  GainLossPeriod  \
0              NaN             NaN             NaN       NaN             NaN
1              NaN             NaN             NaN       NaN             NaN
2              NaN             NaN             NaN       NaN             NaN
3              NaN             NaN             NaN       NaN             NaN
4              NaN             NaN             NaN       NaN             NaN

   PhaseInPercent  PhaseInPeriods  PhaseInType  GainLossRecognition  \
0             NaN             NaN          NaN                  NaN
1             NaN             NaN          NaN                  NaN
2             NaN             NaN          NaN                  NaN
3             NaN             NaN          NaN                  NaN
4             NaN             NaN          NaN                  NaN

   AssetSmoothingBaseline  ExpectedReturnMethod  AddSubtractGainLoss  \
0                     NaN                   NaN                  NaN
1                     NaN                   NaN                  NaN
2                     NaN                   NaN                  NaN
3                     NaN                   NaN                  NaN
4                     NaN                   NaN                  NaN

   UpperCorridor  LowerCorridor  ActCostMethCode  FundMethCode_1  \
0            NaN            NaN              1.0             1.0
1            NaN            NaN              1.0             1.0
2            NaN            NaN              1.0             1.0
3            NaN            NaN              1.0             1.0
4            NaN            NaN              1.0             1.0

   FundMethCode_2  PayrollGrowthAssumption  TotAmortPeriod  \
0             1.0                    0.045             NaN
1             1.0                    0.045             NaN
2             1.0                    0.045             NaN
3             1.0                    0.045             NaN
4             1.0                    0.045             NaN

   RemainingAmortPeriod  UAALYearEstablished  WageInflation  ActAssets_GASB  \
0                  13.0                  NaN          0.045       8028471.0
1                  20.0                  NaN          0.045       8100846.5
2                   NaN                  NaN          0.045       8312500.0
3                  20.0                  NaN          0.045       8563945.0
4                  20.0                  NaN          0.045       8935358.0
```

	ActLiabilities_GASB	ActFundedRatio_GASB	UAAL_GASB	ActLiabilities_other
0	8010123.0	1.002	-18348.0	0.0
1	8493469.0	0.954	392623.0	0.0
2	9124279.0	0.911	811779.0	0.0
3	9546478.0	0.897	982533.0	0.0
4	10634976.0	0.840	1699618.0	0.0

	payroll	RequiredContribution	PercentReqContPaid	TotalPensionLiability
0	2408543.0	122483.0	1.0	NaN
1	2547775.0	123887.0	1.0	NaN
2	2677025.0	154218.0	1.0	NaN
3	2702393.0	170713.0	1.0	NaN
4	2982122.0	195846.0	1.0	NaN

	NetPosition	NetPensionLiability	ActAssets_est	ActLiabilities_est
0	NaN	NaN	NaN	NaN
1	NaN	NaN	NaN	NaN
2	NaN	NaN	NaN	NaN
3	NaN	NaN	NaN	NaN
4	NaN	NaN	NaN	NaN

	ActFundedRatio_est	RequiredContribution_est	ActFundedRatio_GASB67
0	NaN	NaN	NaN
1	NaN	NaN	NaN
2	NaN	NaN	NaN
3	NaN	NaN	NaN
4	NaN	NaN	NaN

	InvestmentConsultantName	InvestmentConsultantCode	InvestmentReturn_1yr
0	AM South Bank, NA	99.0	-0.0636
1	AM South Bank, NA	99.0	-0.0929
2	AM South Bank, NA	99.0	0.1648
3	AM South Bank, NA	99.0	0.1006
4	AM South Bank, NA	99.0	0.1098

	InvestmentReturn_2yr	InvestmentReturn_3yr	InvestmentReturn_4yr
0	NaN	0.0502	NaN
1	NaN	-0.0232	NaN
2	NaN	-0.0035	NaN
3	NaN	0.0541	NaN
4	NaN	0.1274	NaN

	InvestmentReturn_5yr	InvestmentReturn_7yr	InvestmentReturn_8yr
0	0.0807	NaN	NaN
1	0.0288	NaN	NaN
2	0.0412	NaN	NaN

```
3                0.0377                    NaN                    NaN
4                0.0401                    NaN                    NaN

   InvestmentReturn_10yr  InvestmentReturn_12yr  InvestmentReturn_15yr  \
0                    NaN                    NaN                    NaN
1                    NaN                    NaN                    NaN
2                 0.0755                    NaN                    NaN
3                 0.0851                    NaN                    NaN
4                 0.0778                    NaN                    NaN

   InvestmentReturn_20yr  InvestmentReturn_25yr  InvestmentReturn_30yr  \
0                    NaN                    NaN                    NaN
1                    NaN                    NaN                    NaN
2                    NaN                    NaN                    NaN
3                    NaN                    NaN                    NaN
4                    NaN                    NaN                    NaN

   InvestmentReturn_LongTerm  InvestmentReturn_LTStartYear  GrossReturns  \
0                        NaN                           NaN           NaN
1                        NaN                           NaN           NaN
2                        NaN                           NaN           NaN
3                        NaN                           NaN           NaN
4                        NaN                           NaN           NaN

   GeoReturn_est  GeoGrowth_est  InvestmentReturn_1yr_est  \
0       -0.06360            NaN                       0.0
1       -0.07837            NaN                       0.0
2       -0.00355            NaN                       0.0
3        0.02153            NaN                       0.0
4        0.03860            NaN                       0.0

   InvestmentReturn_5yr_est  InvestmentReturn_10yr_est  AvgReturn_3yr  \
0                       0.0                        0.0            NaN
1                       0.0                        0.0            NaN
2                       0.0                        0.0          0.003
3                       0.0                        0.0          0.057
4                       0.0                        0.0          0.125

   AvgReturn_5yr  AvgReturn_10yr  expense_SecLendMgmtFees  contrib_EE_regular  \
0            NaN             NaN                   -385.0            130965.0
1            NaN             NaN                   -333.0            149130.0
2            NaN             NaN                   -266.0            159763.0
3            NaN             NaN                   -283.0            166973.0
4          0.044             NaN                   -448.0            158128.0

   contrib_ER_regular  contrib_ER_state  contrib_EE_PurchaseService  \
0            122483.0               NaN                         NaN
```

```
1            123887.0               NaN                          NaN
2            154218.0               NaN                          NaN
3            170713.0               NaN                          NaN
4            195846.0               NaN                          NaN

   contrib_EE_other  contrib_ER_other  contrib_other  POB_Flag  POB_Amount  \
0               NaN               NaN         1273.0       0.0         NaN
1               NaN               NaN         2091.0       0.0         NaN
2               NaN               NaN         2521.0       0.0         NaN
3               NaN               NaN         1575.0       0.0         NaN
4               NaN               NaN         2185.0       0.0         NaN

   contrib_tot  FairValueChange_investments  FairValueChange_RealEstate  \
0     254721.0                    -874433.0                         NaN
1     275108.0                    -953188.0                         NaN
2     316502.0                     668539.0                         NaN
3     339261.0                     457981.0                         NaN
4     356159.0                     545826.0                         NaN

   income_interest  income_dividends  income_InterestAndDividends  \
0              NaN               NaN                     343517.0
1              NaN               NaN                     297845.0
2              NaN               NaN                     271698.0
3              NaN               NaN                     268876.0
4              NaN               NaN                     295631.0

   income_RealEstate  income_PrivateEquity  income_alternatives  \
0                NaN                   NaN                  NaN
1                NaN                   NaN                  NaN
2                NaN                   NaN                  NaN
3                NaN                   NaN                  NaN
4                NaN                   NaN                  NaN

   income_international  income_OtherInvestments  expense_RealEstate  \
0                   NaN                      NaN                 NaN
1                   NaN                      NaN                 NaN
2                   NaN                      NaN                 NaN
3                   NaN                      NaN                 NaN
4                   NaN                      NaN                 NaN

   expense_PrivateEquity  expense_alternatives  expense_OtherInvestments  \
0                    NaN                   NaN                       NaN
1                    NaN                   NaN                       NaN
2                    NaN                   NaN                       NaN
3                    NaN                   NaN                       NaN
4                    NaN                   NaN                       NaN
```

```
   expense_investments  FVChange_SecLend  income_SecuritiesLending  \
0              -1593.0               NaN                   20922.0
1              -2331.0               NaN                    5741.0
2              -2380.0               NaN                    3461.0
3              -2390.0               NaN                    4892.0
4              -2652.0               NaN                   17604.0

   expense_SecuritiesLending  income_SecuritiesLendingRebate  \
0                   -19381.0                        -18996.0
1                    -4427.0                         -4094.0
2                    -2397.0                         -2131.0
3                    -3601.0                         -3318.0
4                   -15396.0                        -14948.0

   FVChange_SecLend_UG  income_OtherAdditions  income_net  \
0                  NaN                    NaN   -276247.0
1                  NaN                    NaN   -381252.0
2                  NaN                    NaN   1255423.0
3                  NaN                    NaN   1065019.0
4                  NaN                    NaN   1197172.0

   expense_TotBenefits  expense_RetBenefits  expense_DisabilityBenefits  \
0            -396621.0            -371715.0                         NaN
1            -414821.0            -389856.0                         NaN
2            -448083.0            -423027.0                         NaN
3            -480064.0            -448658.0                         NaN
4            -518308.0            -487348.0                         NaN

   expense_DeathBenefits  expense_DROPBenefits  expense_SurvivorBenefits  \
0                    NaN                   NaN                       NaN
1                    NaN                   NaN                       NaN
2                    NaN                   NaN                       NaN
3                    NaN                   NaN                       NaN
4                    NaN                   NaN                       NaN

   expense_COLABenefits  expense_LumpSumBenefits  expense_OtherBenefits  \
0                   NaN                      NaN               -24906.0
1                   NaN                      NaN               -24965.0
2                   NaN                      NaN               -25056.0
3                   NaN                      NaN               -31406.0
4                   NaN                      NaN               -30960.0

   expense_refunds  expense_AdminExpenses  expense_Depreciation  \
0              NaN                -4578.0                -330.0
1              NaN                -5582.0                -235.0
2              NaN                -5843.0                -278.0
3              NaN                -5892.0                -269.0
```

```
4              NaN               -6898.0               -294.0

   expense_OtherDeductions  expense_net  adjustment_MktAssets  MktAssets_net  \
0                  -4074.0    -405603.0                   NaN      7236735.0
1                 -10410.0    -431048.0                   NaN      6424435.0
2                  -2842.0    -457046.0                   NaN      7222812.0
3                  -6008.0    -492233.0                   NaN      7795598.0
4                  -2755.0    -528255.0                   NaN      8464515.0

   BegMktAssets_net  contrib_ER_tot  contrib_other_tot  FairValueChange_tot  \
0         7918585.0        122483.0             1273.0            -874433.0
1         7236735.0        123887.0             2091.0            -953188.0
2         6424435.0        154218.0             2521.0             668539.0
3         7222812.0        170713.0             1575.0             457981.0
4         7795598.0        195846.0             2185.0             545826.0

   income_interest_dividends_tot  expense_investments_tot  SecLend_tot  \
0                       343517.0                  -1593.0       1541.0
1                       297845.0                  -2331.0       1314.0
2                       271698.0                  -2380.0       1064.0
3                       268876.0                  -2390.0       1291.0
4                       295631.0                  -2652.0       2208.0

   investments_net  expense_other_tot  ContributionFY        ActuarialFirm  \
0        -530968.0            -4404.0          2004.0     Buck Consultants
1        -656360.0           -10645.0          2005.0               Mellon
2         938921.0            -3120.0          2006.0  Cavanaugh Macdonald
3         725758.0            -6277.0          2007.0  Cavanaugh Macdonald
4         841013.0            -3049.0          2008.0  Cavanaugh Macdonald

   ActuarialFirmCode  NormCostRate_tot  NormCostRate_EE  NormCostRate_ER  \
0                2.0            0.1022           0.0501           0.0521
1                8.0            0.0988           0.0501           0.0487
2                3.0            0.0996           0.0501           0.0495
3                3.0            0.0988           0.0501           0.0487
4                3.0            0.0988           0.0501           0.0487

   ReqContRate_ER  ReqContRate_tot  ReqContRate_ER_Stat  ReqContRate_tot_Stat  \
0          0.0455           0.0956                  NaN                   NaN
1          0.0632           0.1133                  NaN                   NaN
2          0.0722           0.1223                  NaN                   NaN
3          0.0767           0.1268                  NaN                   NaN
4          0.0933           0.1434                  NaN                   NaN

   NormCostAmount_tot  NormCostAmount_EE  NormCostAmount_ER  ReqContAmount_ER  \
0                 NaN                NaN                NaN               NaN
1                 NaN                NaN                NaN               NaN
```

```
2                NaN                NaN                NaN                NaN
3                NaN                NaN                NaN                NaN
4                NaN                NaN                NaN                NaN

   ReqContAmount_tot  ReqContAmount_ER_Stat  ReqContAmount_tot_Stat  \
0                NaN                    NaN                     NaN
1                NaN                    NaN                     NaN
2                NaN                    NaN                     NaN
3                NaN                    NaN                     NaN
4                NaN                    NaN                     NaN

   NormCostRate_tot_est  NormCostRate_EE_est  NormCostRate_ER_est  \
0                   0.0                  0.0                  0.0
1                   0.0                  0.0                  0.0
2                   0.0                  0.0                  0.0
3                   0.0                  0.0                  0.0
4                   0.0                  0.0                  0.0

   ReqContRate_ER_est  ProjectedPayroll  UAALRate  \
0                 0.0               NaN   -0.0066
1                 0.0               NaN    0.0145
2                 0.0               NaN    0.0227
3                 0.0               NaN    0.0280
4                 0.0               NaN    0.0446

   beneficiaries_DisabilityRetirees  beneficiaries_DependentSurvivors  \
0                            2537.0                               NaN
1                            2671.0                               NaN
2                               NaN                               NaN
3                            2950.0                               NaN
4                            3140.0                               NaN

   actives_tot  ActiveSalaries  ActiveAge_avg  ActiveTenure_avg  \
0      80256.0      2408543.00            NaN               NaN
1      81545.0      2525514.00            NaN               NaN
2      82304.0      2628626.25            NaN               NaN
3      81249.0      2625617.50            NaN               NaN
4      82830.0      2808823.00            NaN               NaN

   ActiveSalary_avg  InactiveVestedMembers  InactiveNonVested  \
0            30.011                 7720.0                NaN
1            30.971                 8898.0                NaN
2            31.938                 9385.0                NaN
3            32.316                 9507.0                NaN
4            33.911                 9959.0                NaN

   beneficiaries_tot  benefits_tot  BeneficiaryAge_avg  \
```

```
0            27064.0     378196.06                NaN
1            27987.0     411556.94                NaN
2            28951.0     454751.06                NaN
3            29998.0     497945.22                NaN
4            31513.0     539462.06                NaN

   BeneficiaryBenefit_avg  beneficiaries_ServiceRetirees  \
0                  13.974                        21541.0
1                  14.705                        22307.0
2                  15.708                        28951.0
3                  16.599                        23969.0
4                  17.119                        25260.0

   benefits_ServiceRetirees  ServiceRetireeAge_avg  ServiceRetireeBenefit_avg  \
0                 332821.94                    NaN                        NaN
1                 351476.38                    NaN                        NaN
2                 430979.13                    NaN                        NaN
3                 401661.66                    NaN                        NaN
4                 431066.75                    NaN                        NaN

   ServiceRetAge_avg  ServiceRetTenure_avg  benefits_DisabilityRetirees  \
0                NaN                   NaN                     25456.566
1                NaN                   NaN                     26915.596
2                NaN                   NaN                           NaN
3                NaN                   NaN                     31075.668
4                NaN                   NaN                     33441.309

   beneficiaries_survivors  beneficiaries_SpousalSurvivors  \
0                   2986.0                             NaN
1                   3009.0                             NaN
2                      NaN                             NaN
3                   3079.0                             NaN
4                   3113.0                             NaN

   beneficiaries_other  DROPMembers  OtherMembers  TotMembership  \
0                  NaN          NaN           NaN       115040.0
1                  NaN        428.0           NaN       118858.0
2                  NaN        923.0           NaN       121563.0
3                  NaN       1440.0           NaN       122194.0
4                  NaN       1753.0           NaN       126055.0

   ActiveSalary_avg_est  BeneficiaryBenefit_avg_est  PVFB_InactiveNonVested  \
0                   0.0                         1.0                     NaN
1                   0.0                         1.0                     NaN
2                   0.0                         1.0                     NaN
3                   0.0                         1.0                     NaN
4                   0.0                         1.0                     NaN
```

	PVFB_active	PVFB_InactiveVested	PVFB_retiree	PVFB_other	PVFB_tot
0	6573837.268	NaN	3244967.0	NaN	9.818804e+06
1	6786095.376	NaN	3580584.0	NaN	1.036668e+07
2	7150768.438	NaN	3928131.0	NaN	1.107890e+07
3	7125585.694	NaN	4496854.0	NaN	1.162244e+07
4	7835514.779	NaN	5076621.0	NaN	1.291214e+07

	PVFNC_tot	PVFC_EE	PVFNC_ER	PVFS	AccruedLiab_active	PVFC_tot
0	1808681.068	957545.572	851135.496	NaN	NaN	NaN
1	1873210.413	1003304.771	869905.642	NaN	NaN	NaN
2	1954619.927	1045916.651	908703.276	NaN	NaN	NaN
3	2075961.238	1115061.225	960900.013	NaN	NaN	NaN
4	2277159.873	1223166.025	1053993.848	NaN	NaN	NaN

	PVFC_ER	ActAssets_BalSht	TotFund_BnchmrkRtrn	Leverage_Flag
0	NaN	8028471.0	NaN	0.0
1	NaN	8100846.5	NaN	0.0
2	NaN	8312500.0	NaN	0.0
3	NaN	8563945.0	NaN	0.0
4	NaN	8935358.0	NaN	0.0

	Leverage_Total_Actl	Leverage_Total_Trgt	EQTotal_Rtrn	EQTotal_Actl
0	NaN	NaN	-0.25645	0.4653
1	NaN	NaN	-0.17381	0.4649
2	NaN	NaN	0.25830	0.5479
3	NaN	NaN	0.16005	0.5786
4	NaN	NaN	0.16873	0.5872

	EQTotal_Trgt	FITotal_Rtrn	FITotal_Actl	FITotal_Trgt	RETotal_Rtrn
0	NaN	0.1075	0.5347	NaN	NaN
1	NaN	-0.0130	0.5351	NaN	NaN
2	NaN	0.1047	0.4521	NaN	NaN
3	NaN	0.0486	0.4214	NaN	NaN
4	NaN	0.0475	0.4128	NaN	NaN

	RETotal_Actl	RETotal_Trgt	AltMiscTotal_Rtrn	AltMiscTotal_Actl
0	0.0	NaN	NaN	0.0
1	0.0	NaN	NaN	0.0
2	0.0	NaN	NaN	0.0
3	0.0	NaN	NaN	0.0
4	0.0	NaN	NaN	0.0

	AltMiscTotal_Trgt	PETotal_Rtrn	PETotal_Actl	PETotal_Trgt	HFTotal_Rtrn
0	NaN	NaN	0.0	NaN	NaN
1	NaN	NaN	0.0	NaN	NaN
2	NaN	NaN	0.0	NaN	NaN

```
3                NaN           NaN           0.0           NaN           NaN
4                NaN           NaN           0.0           NaN           NaN

   HFTotal_Actl  HFTotal_Trgt  COMDTotal_Rtrn  COMDTotal_Actl  COMDTotal_Trgt  \
0           0.0           NaN             NaN             0.0             NaN
1           0.0           NaN             NaN             0.0             NaN
2           0.0           NaN             NaN             0.0             NaN
3           0.0           NaN             NaN             0.0             NaN
4           0.0           NaN             NaN             0.0             NaN

   CashTotal_Rtrn  CashTotal_Actl  CashTotal_Trgt  OtherTotal_Rtrn  \
0             NaN             0.0             NaN              NaN
1             NaN             0.0             NaN              NaN
2             NaN             0.0             NaN              NaN
3             NaN             0.0             NaN              NaN
4             NaN             0.0             NaN              NaN

   OtherTotal_Actl  OtherTotal_Trgt  Duration_Type Duration_describe  \
0              0.0              NaN            NaN               NaN
1              0.0              NaN            NaN               NaN
2              0.0              NaN            NaN               NaN
3              0.0              NaN            NaN               NaN
4              0.0              NaN            NaN               NaN

   Total_Duration  Total_MktVal_Duration
0             NaN                    NaN
1             NaN                    NaN
2             NaN                    NaN
3             NaN                    NaN
4             NaN                    NaN
```

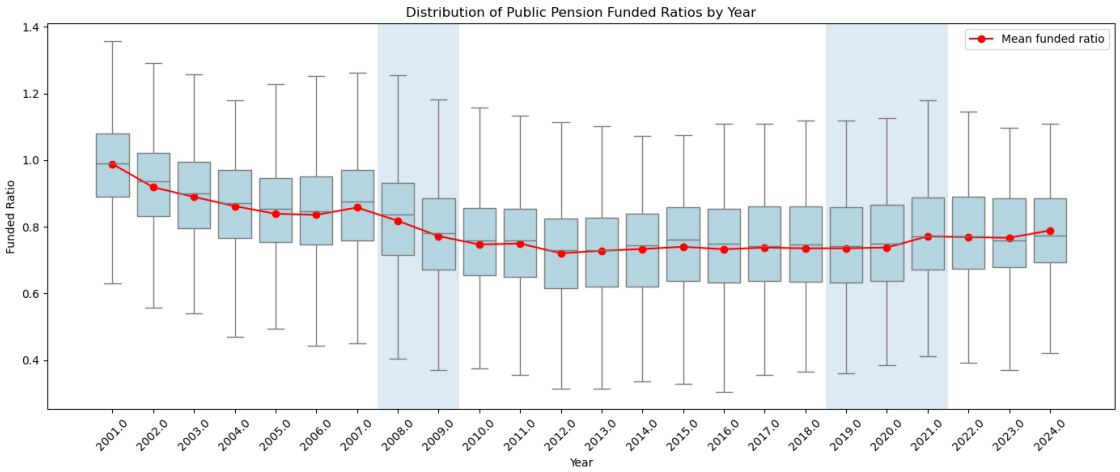
1.2 Discussion

1.2.1 1. Funded Ratio

One of the core concepts in retirement actuarial work is the funded ratio. It reflects "a pension fund's current financial position" (DeNederlandscheBank).
In general, funded ratio = $\frac{\text{Actuarial Value of Assets}}{\text{Actuarial Value of Liability}}$. We draw the following plot to see how did the funded ratio of US public pension plan change over time.

[3]:
```
plt.figure(figsize=(14, 6))
sns.boxplot(
    data=pension_df,
    x="fy",
    y="ActFundedRatio_GASB",
    color="lightblue",
    showfliers=False
)
```

```
mean_by_year = (
    pension_df.groupby("fy")["ActFundedRatio_GASB"]
      .mean()
      .reset_index()
)
plt.plot(
    range(len(mean_by_year)),
    mean_by_year["ActFundedRatio_GASB"],
    color="red",
    marker="o",
    label="Mean funded ratio"
)
years = mean_by_year["fy"].tolist()
x_2008 = years.index(2008)
x_2019 = years.index(2019)

plt.axvspan(x_2008 - 0.5, x_2008 + 1.5, alpha=0.15)
plt.axvspan(x_2019 - 0.5, x_2019 + 2.5, alpha=0.15)


plt.xlabel("Year")
plt.ylabel("Funded Ratio")
plt.legend()
plt.title("Distribution of Public Pension Funded Ratios by Year")

plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
```



From the plot above, we observe a broad downward shift in the distribution of funded ratios following the 2008 financial crisis, reflected in declines across the interquartile range as well as in

the mean funded ratio. This suggests that the deterioration in funding levels was systemic rather than plan-specific, driven by widespread asset losses and insufficient contribution adjustments. Notably, the aggregate funded ratio has not returned to its pre-crisis (2007) level, indicating the presence of persistent structural funding shortfalls rather than a purely cyclical shock.

In contrast, since the onset of the COVID-19 period in 2019, the mean funded ratio exhibits a gradual upward trend, which may caused by the high inflation.

1.2.2 2. Inflation-adjusted UAAL

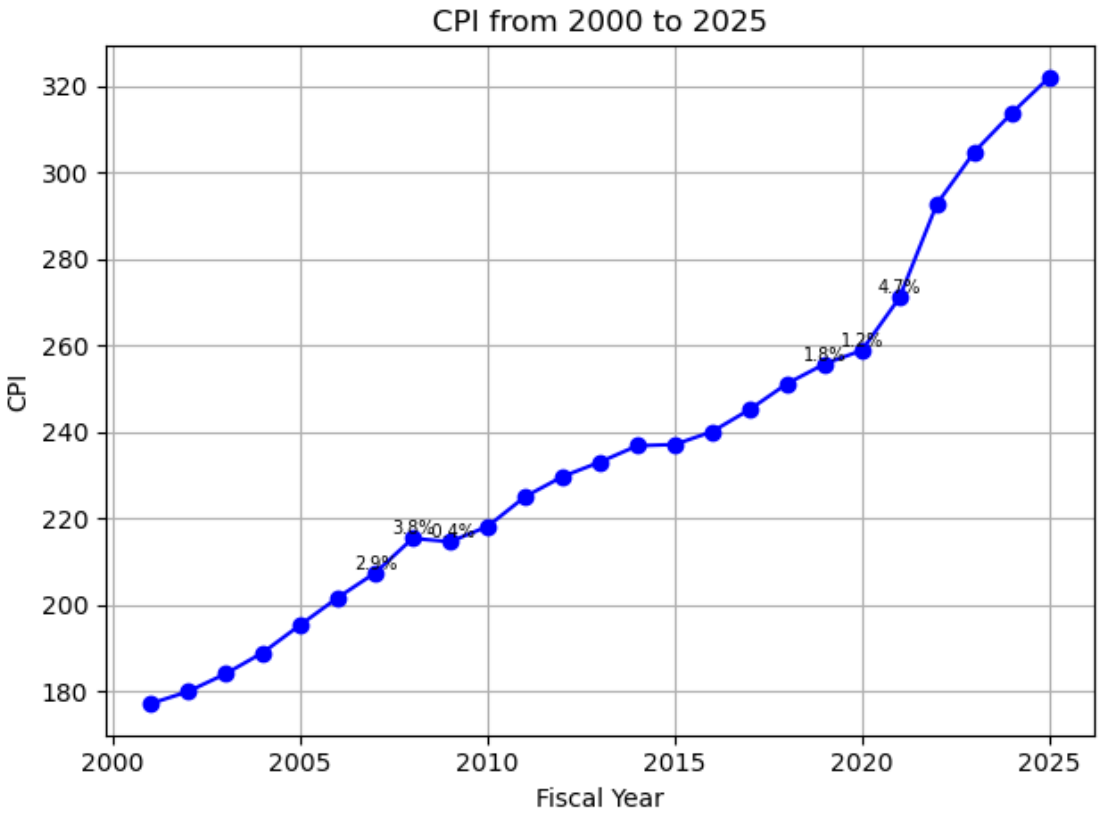
Therefore, we will calculate the inflation adjusted UAAL to compare the Unfunded Actuarial Accrued Liability during these two shock period. For the inflation, we will use the CPI-U dataset published by BLS.

[19]:
```
cpi_df = pd.read_excel("historical-cpi-u-202512.xlsx")
cpi_df["Year"] = pd.to_numeric(cpi_df["Year"], errors="coerce")
cpi_df = cpi_df[cpi_df["Year"] > 2000]
cpi_df = cpi_df.drop(columns=["Indent Level"])
cpi_df["Oct."] = pd.to_numeric(cpi_df["Oct."], errors="coerce")
```

[ ]:
```
months = ["Jan.","Feb.","Mar.","Apr.","May","Jun.","Jul.","Aug.","Sep.","Oct.
  ↪","Nov.","Dec."]
cpi_df["CPI_annual_avg"] = cpi_df[months].mean(axis=1)\
```

[52]:
```
cpi_df["CPI_pct_change"] = cpi_df["CPI_annual_avg"].pct_change() * 100
```

[59]:
```
plt.plot(
    cpi_df["Year"],
    cpi_df["CPI_annual_avg"],
    color="blue",
    marker="o"
)
for i in range(1, len(cpi_df)):
    if cpi_df["Year"].iloc[i] in [2007, 2008, 2009, 2019,2020,2021]:
        plt.text(
        cpi_df["Year"].iloc[i],
        cpi_df["CPI_annual_avg"].iloc[i],
        f'{cpi_df["CPI_pct_change"].iloc[i]:.1f}%',
        fontsize=7,
        ha='center',
        va='bottom'
    )
plt.title("CPI from 2000 to 2025")
plt.xlabel("Fiscal Year")
plt.ylabel("CPI")
plt.tight_layout()
plt.grid(True)
plt.show()
```

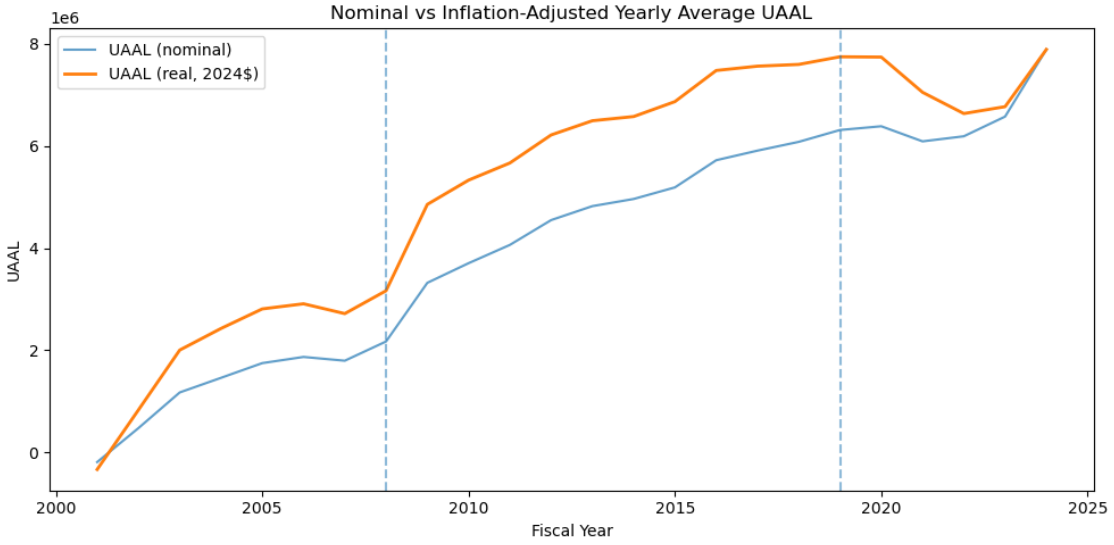


We picked 2024 as our base year as it is the latest one in the public pension plan dataset.

[ ]:
```
pension_df["UAAL_nominal"] = pension_df["UAAL_GASB"]
cpi_base = cpi_df.loc[cpi_df["Year"] == 2024, "CPI_annual_avg"].iloc[0]
pension_df = pension_df.merge(
    cpi_df[["Year", "CPI_annual_avg"]],
    left_on="fy",
    right_on="Year",
    how="left"
)
pension_df["UAAL_real"] = (pension_df["UAAL_GASB"]* cpi_base/␣
 ↪pension_df["CPI_annual_avg"])
```

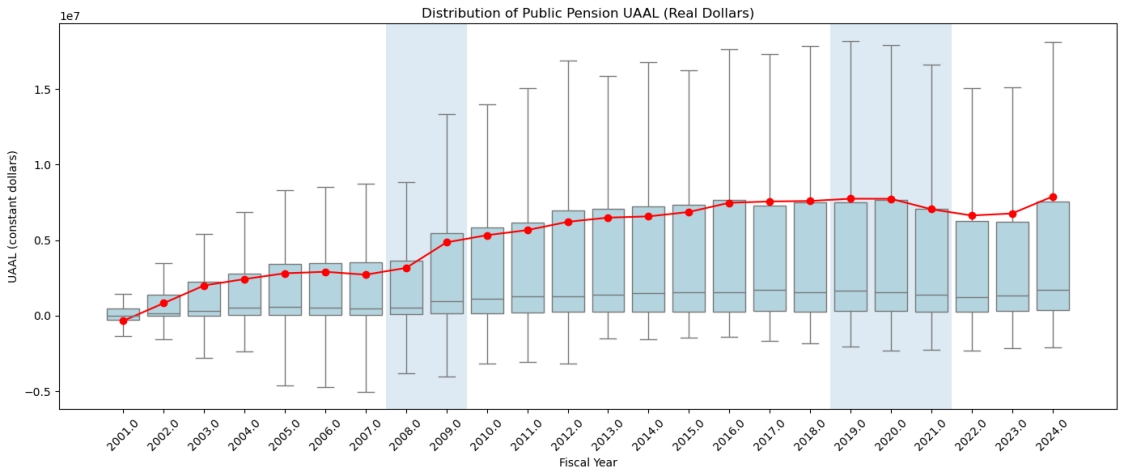
[38]:
```
uaal_by_year = (
    pension_df
    .groupby("fy")[["UAAL_GASB", "UAAL_real"]]
    .mean()
    .reset_index()
)

plt.figure(figsize=(10,5))
```

```
plt.plot(
    uaal_by_year["fy"],
    uaal_by_year["UAAL_GASB"],
    label="UAAL (nominal)",
    alpha=0.7
)

plt.plot(
    uaal_by_year["fy"],
    uaal_by_year["UAAL_real"],
    label="UAAL (real, 2024$)",
    linewidth=2
)

plt.axvline(2008, linestyle="--", alpha=0.5)
plt.axvline(2019, linestyle="--", alpha=0.5)

plt.title("Nominal vs Inflation-Adjusted Yearly Average UAAL")
plt.xlabel("Fiscal Year")
plt.ylabel("UAAL")
plt.legend()
plt.tight_layout()
plt.show()
```



[46]:
```
plt.figure(figsize=(14, 6))

sns.boxplot(
```

```
    data=pension_df,
    x="fy",
    y="UAAL_real",
    color="lightblue",
    showfliers=False
)
mean_by_year_uaal = (
    pension_df.groupby("fy")["UAAL_real"]
      .mean()
      .reset_index()
)
plt.plot(
    range(len(mean_by_year_uaal)),
    mean_by_year_uaal["UAAL_real"],
    color="red",
    marker="o",
    label="Mean Real UAAL"
)
plt.title("Distribution of Public Pension UAAL (Real Dollars)")
plt.xlabel("Fiscal Year")
plt.ylabel("UAAL (constant dollars)")

plt.axvspan(x_2008 - 0.5, x_2008 + 1.5, alpha=0.15)
plt.axvspan(x_2019 - 0.5, x_2019 + 2.5, alpha=0.15)

plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
```



- 2008 financial crisis: There is a sharp upward shift in the entire distribution of real UAAL. The widening boxes and longer upper whiskers suggest that the shock was systemic, affecting

many plans rather than a small subset. This reflects large asset losses that were not offset by inflation, confirming a genuine deterioration in funding. Despite market recovery, the distribution does not return to pre-2008 levels, pointing to structural underfunding rather than a temporary shock.

- COVID19: Although CPI inflation spikes in 2021, the real UAAL does not fall sharply. This shows that post-COVID improvements in nominal funding metrics are partly offset once inflation is removed. The slight dip in the mean around 2021–2022 likely reflects strong asset performance, but the distribution remains wide, indicating uneven recovery across plans.

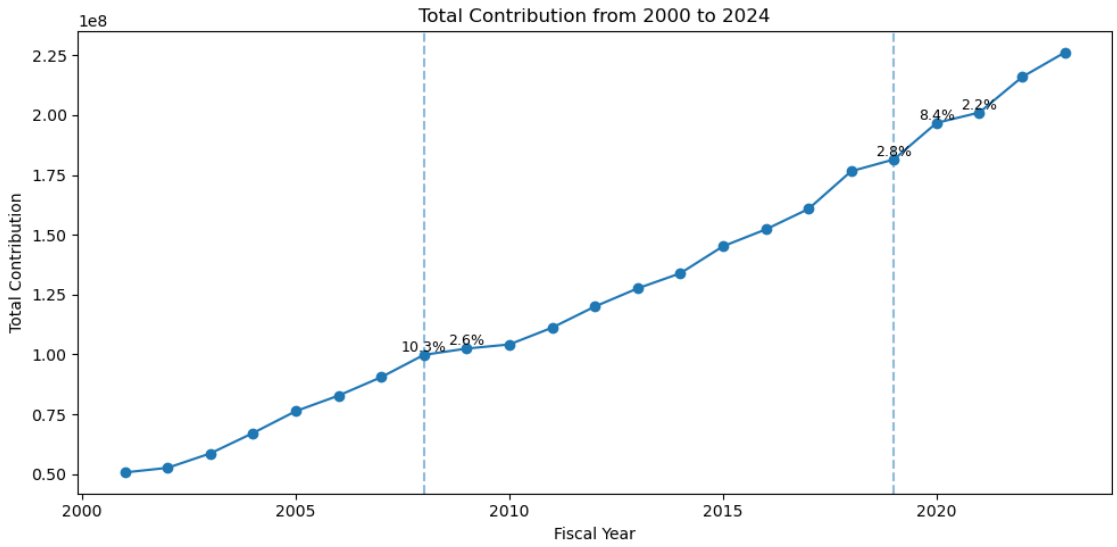
1.2.3 3. Total Contribution

Total contribution is made up of employer regular contributions and employee regular contributions. It indicates the annual cash inflow used to fund pension benefit accruals and amortize existing unfunded liabilities.

[73]:
```
pension_df["Employer_Contribution"] = pension_df["contrib_ER_regular"].fillna(0)
pension_df["Employee_Contribution"] = pension_df["contrib_EE_regular"].fillna(0)

pension_df["Total_Contribution"] = (
    pension_df["Employer_Contribution"]
    + pension_df["Employee_Contribution"]
)

req_by_year = (
    pension_df[pension_df["fy"] < 2024]
    .groupby("fy")["Total_Contribution"]
    .sum()
    .reset_index()
)
req_by_year["pct_change"] = (
    req_by_year["Total_Contribution"].pct_change() * 100
)
```

[74]:
```
plt.figure(figsize=(10,5))
plt.plot(
    req_by_year["fy"],
    req_by_year["Total_Contribution"],
    marker="o"
)

for year in [2008, 2009, 2019, 2020,2021]:
    row = req_by_year[req_by_year["fy"] == year]
    if not row.empty:
        plt.text(
            year,
            row["Total_Contribution"].iloc[0],
            f'{row["pct_change"].iloc[0]:.1f}%',
            ha="center",
```

```
            va="bottom",
            fontsize=9
        )

plt.axvline(2008, linestyle="--", alpha=0.5)
plt.axvline(2019, linestyle="--", alpha=0.5)

plt.title("Total Contribution from 2000 to 2024")
plt.xlabel("Fiscal Year")
plt.ylabel("Total Contribution")
plt.tight_layout()
plt.show()
```



Although UAAL worsened sharply during both crises, total contributions adjusted only gradually, suggesting that contribution policy responds with a delay to sudden market-driven deterioration in pension funding. This smooth trajectory reflects the lagged and smoothed nature of actuarial funding policies, under which contribution increases are phased in over time rather than adjusted abruptly.