Analyzing the Interplay Between Public-Pension Finances and Governmental Finances

Lessons from Linking an Economic Model to a Pension Fund Model

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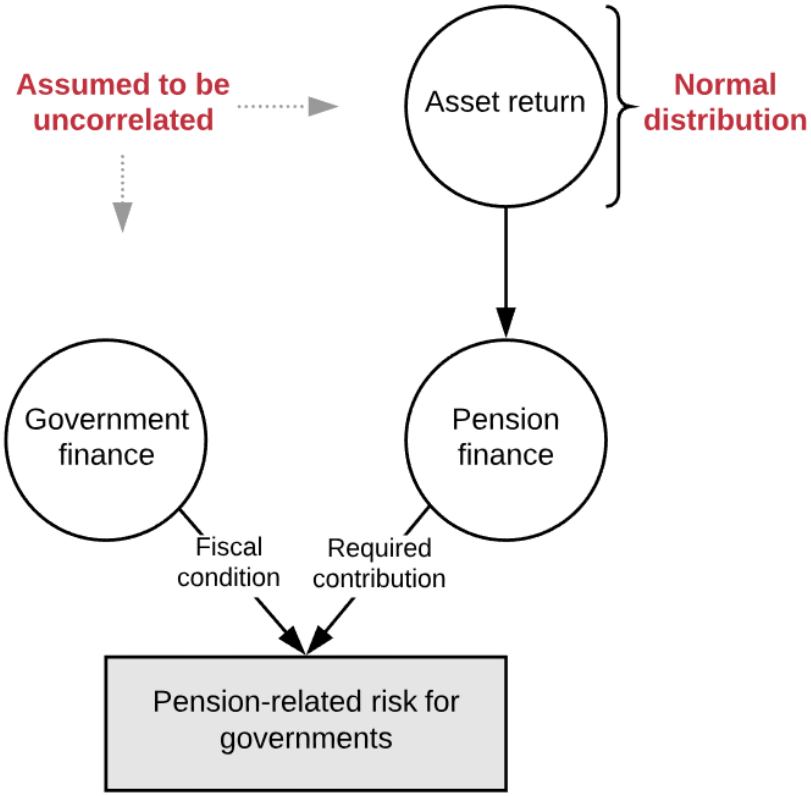
Introduction

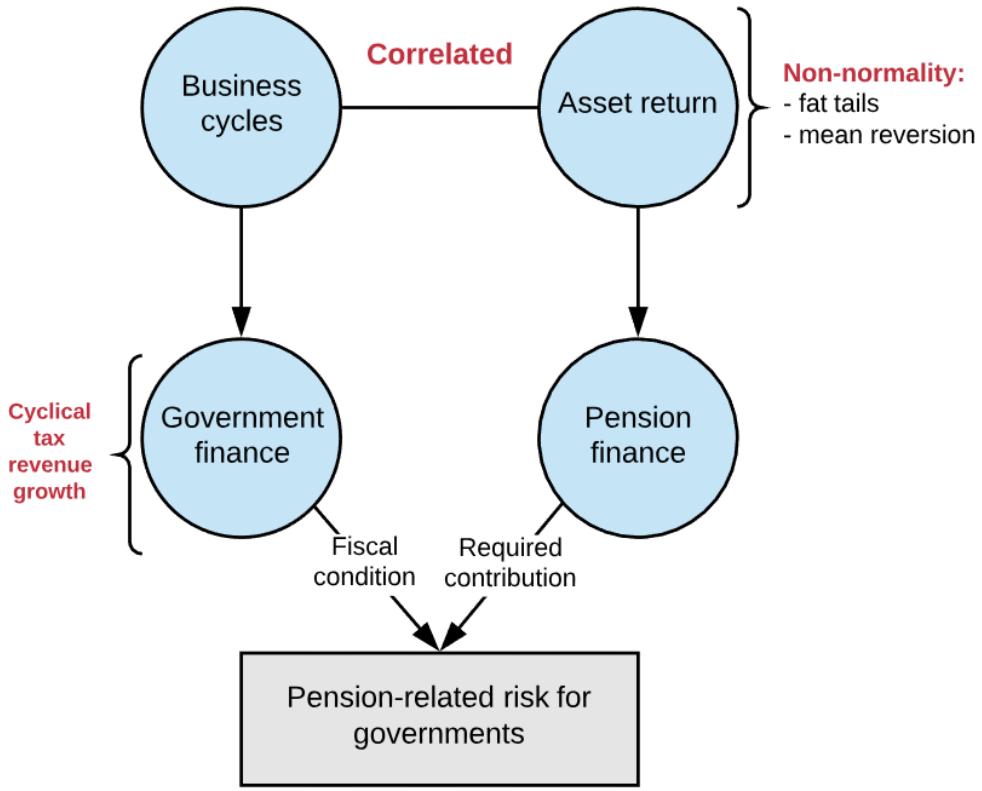
- We and other researchers have examined the investment-related risks to public pension funds and the sponsoring governments using stochastic simulation models.

- These models generally use simple investment return assumptions:
  - Returns follow normal distribution
  - Asset returns and government tax revenue are assumed to be uncorrelated



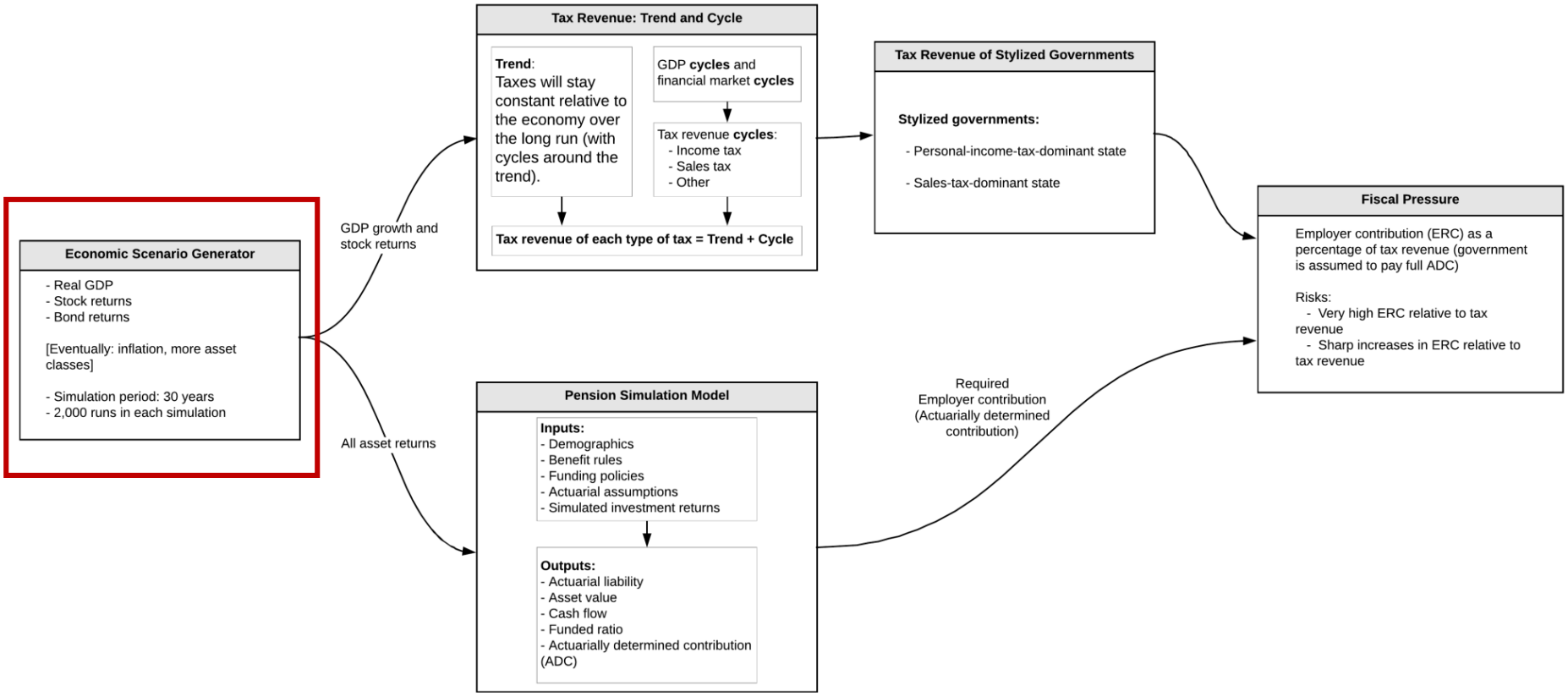
Introduction

- Research suggests that the real world differs from these simple assumptions:
  - Investment returns and tax revenue may be correlated (through business cycles)
  - Non-normality in asset returns
- Poor economy may cause
  - Returns to fall short of expectations
  - Tax revenue to fall short
  - Increase in required contribution may cause additional fiscal pressure



Model Structure and Linkage

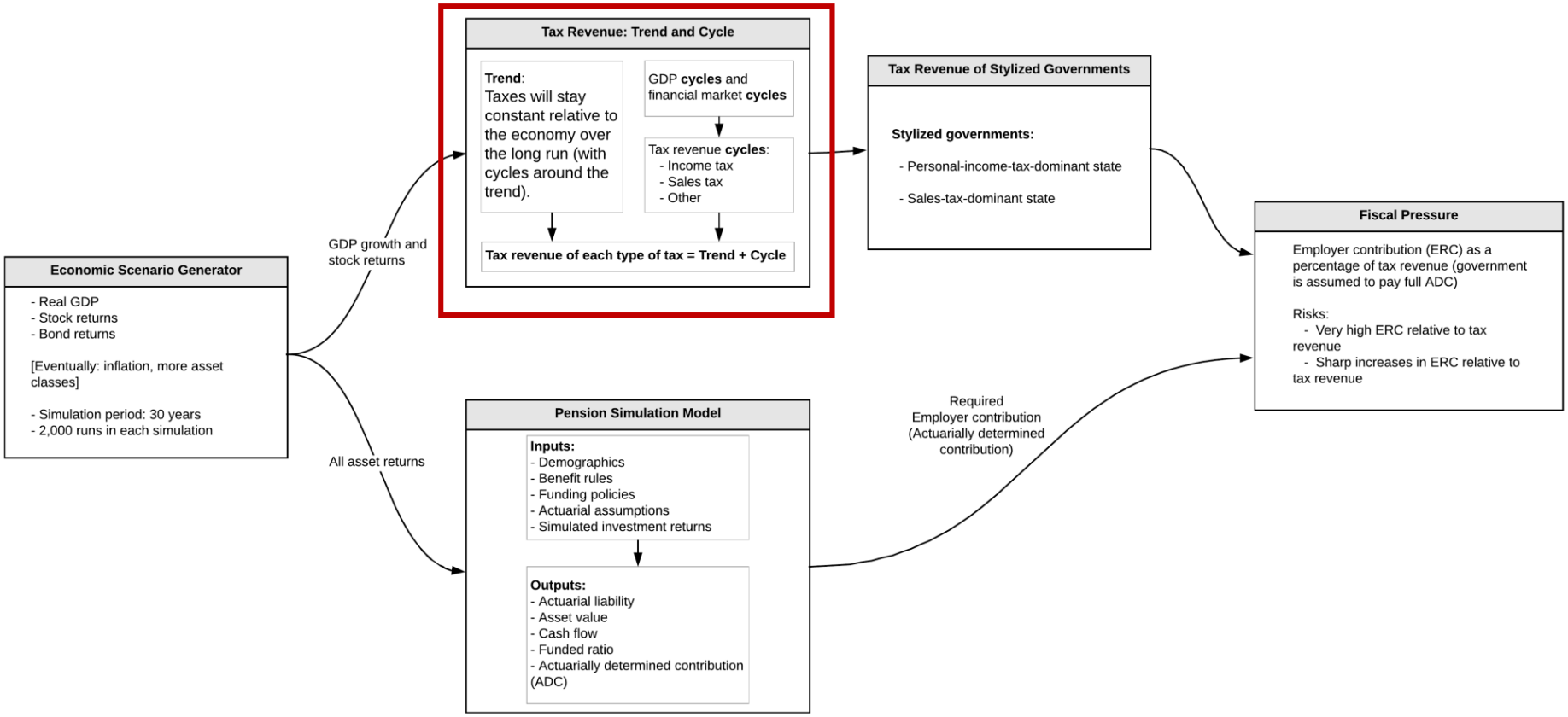
We develop and link a small-scale macro-economic and investment-returns model to a pension fund simulation model and models of governmental tax revenue.



The Economic Scenario Generator (ESG)

- We built a small macroeconomic model that can generate internally consistent stochastic scenarios of growth in real gross domestic product (GDP) and returns from stock and bond investments.
- **GDP growth**
  - Two regimes: economic expansion and recession
  - Modeled as a Markov-switching process; the model captures the general historical pattern of expansions and recessions.
- **Stock return**
  - Two regimes: high-return-low-volatility periods; low-return-high-volatility periods.
  - The ESG allows for correlation between stock returns and GDP growth by aligning their regimes.
- **Bond return**
  - We did not model bond returns econometrically, because of their weak historical relationships to business cycles.
  - Instead, when we produce economic scenarios, we construct stochastic bond returns that have correlations to stock returns that are consistent with historical correlations.

Model Structure and Linkage



Modeling cyclical tax variability for individual taxes

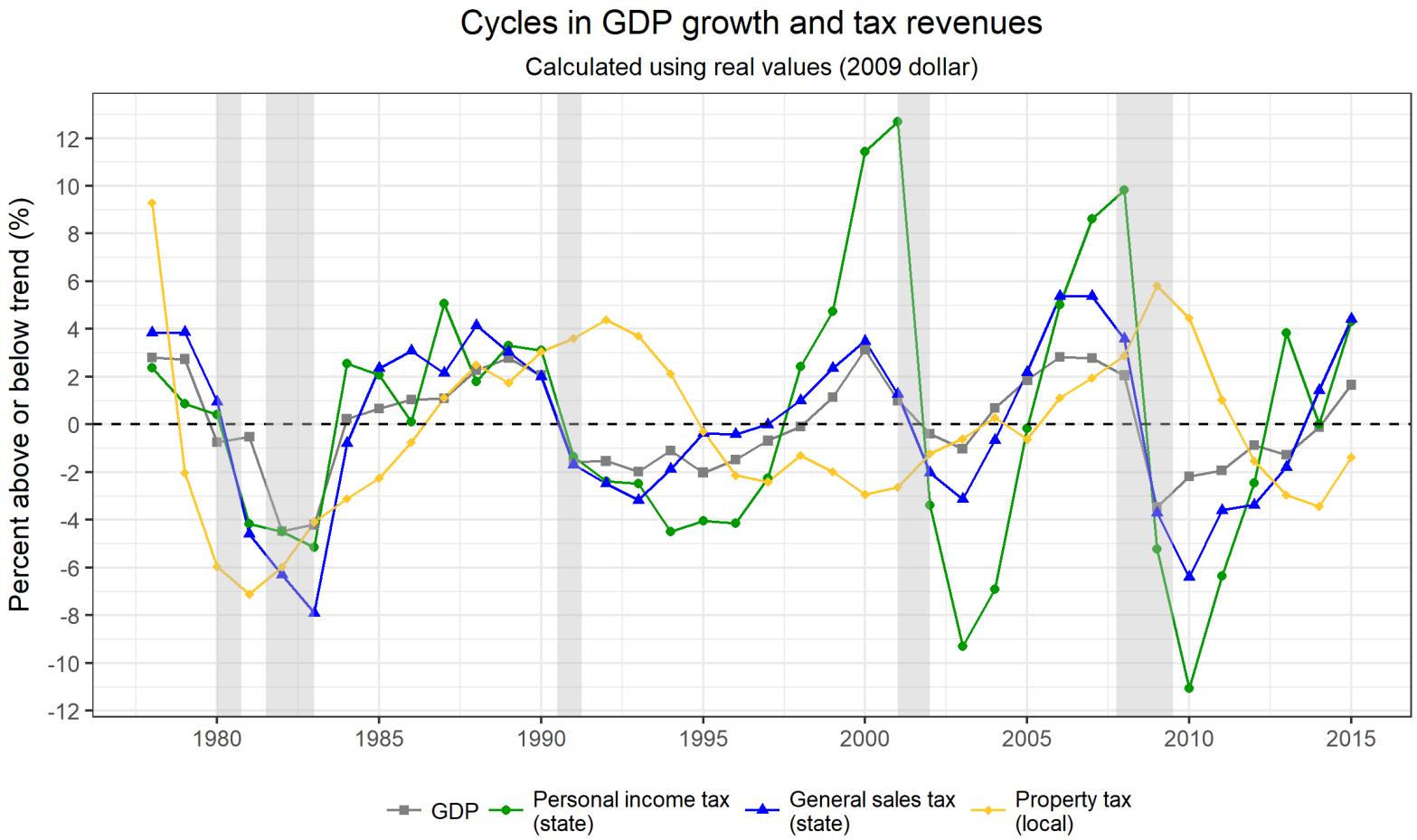
- We estimate the cyclical relationships between taxes and the economy for
  - state personal income taxes,
  - the state general sales tax,
  - state selective sales taxes,
  - and all other state government taxes as a group.
- Individual taxes can exhibit different long-run behavior relative to the economy – for example, progressive income taxes generally will grow more quickly than the economy, while state sales tax bases have been declining relative to the economy.
- In our analyses below, we assume that politicians will adjust tax bases and rates to maintain their shares of the economy over the long run, but that there will be cycles around this trend.

State and local government tax shares in 2015

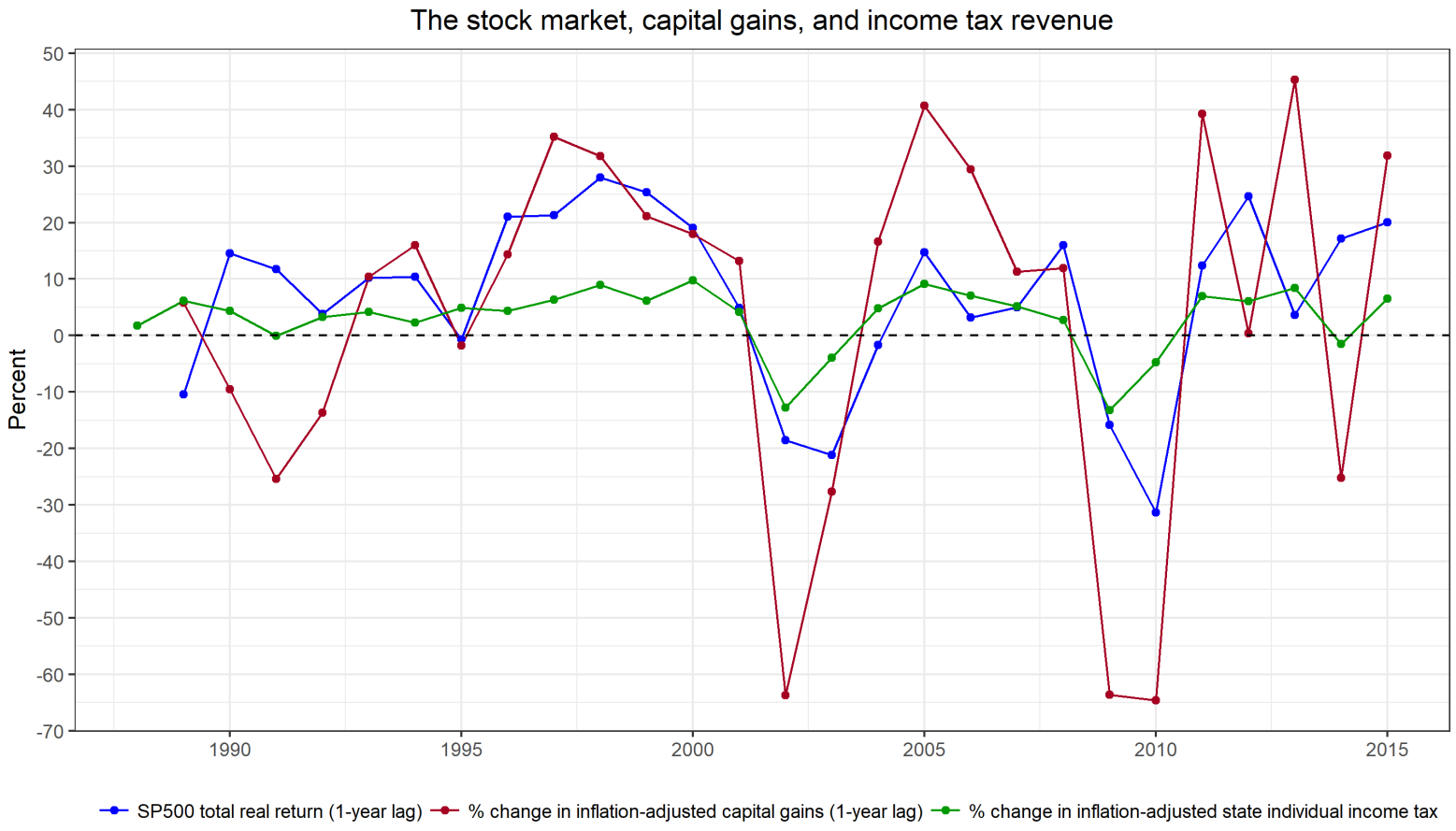
	State government	Local government
Personal income tax	36.9%	4.8%
General sales tax	31.4%	12.5%
Selective sales taxes	15.9%	4.8%
Property tax	1.7%	72.1%
Other	14.1%	5.8%
Total	100.0%	100.0%

Source: U.S. Census Bureau, 2015 Annual Survey of State and Local Government Finances

Cyclical components of main tax revenue sources and cyclical component of real GDP



Cyclical behavior of income tax also depends on how business cycles affect asset values and thereby capital gains from assets



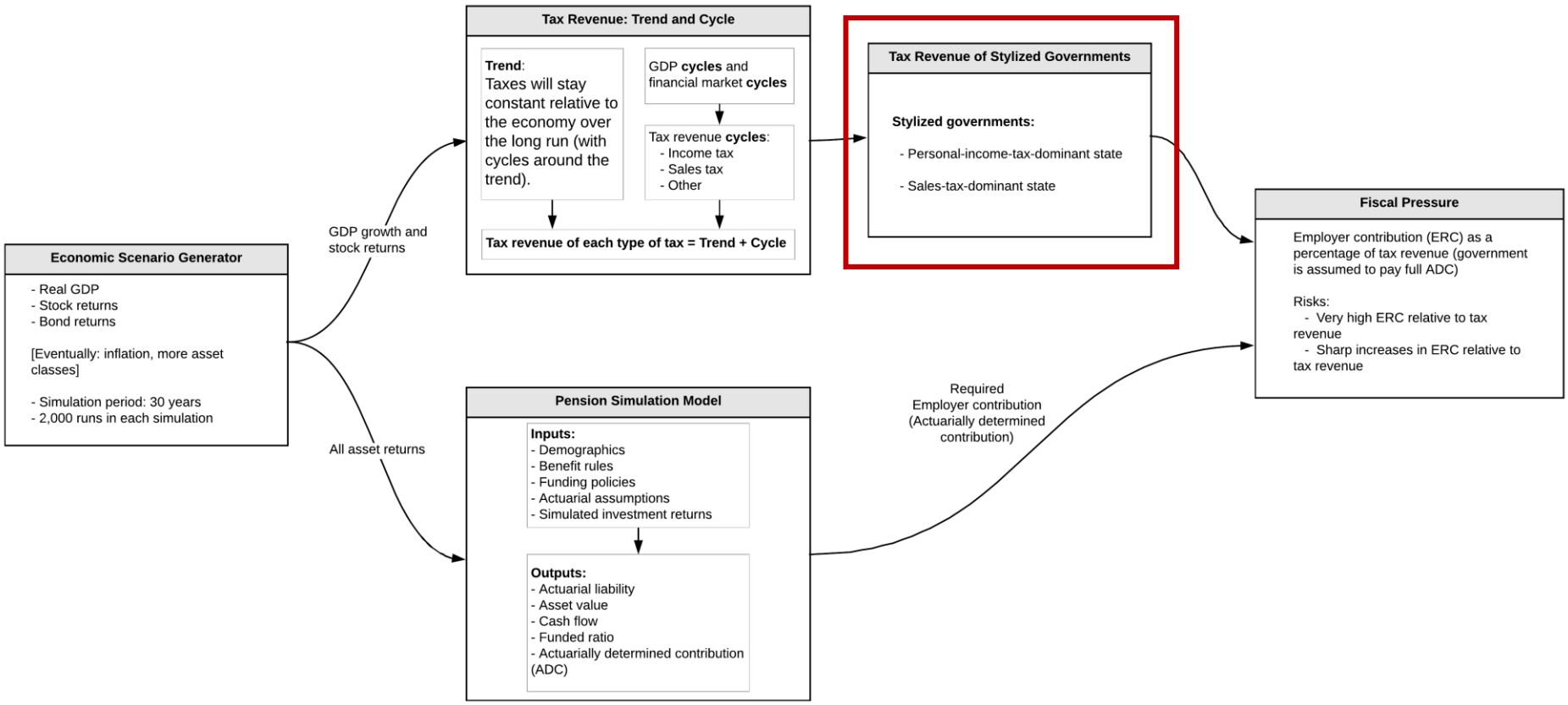
Estimated cyclical tax variability for individual taxes

- **Cyclical growth** rate of real tax revenues: a function of the cyclical growth rate of real GDP and, in the case of the personal income tax, the cyclical growth rate of real stock market values.
- **Trend tax growth**: the same as trend GDP growth (assumed to be 1.9% based on CBO projection)
- **Total tax growth** = Cyclical growth + trend growth

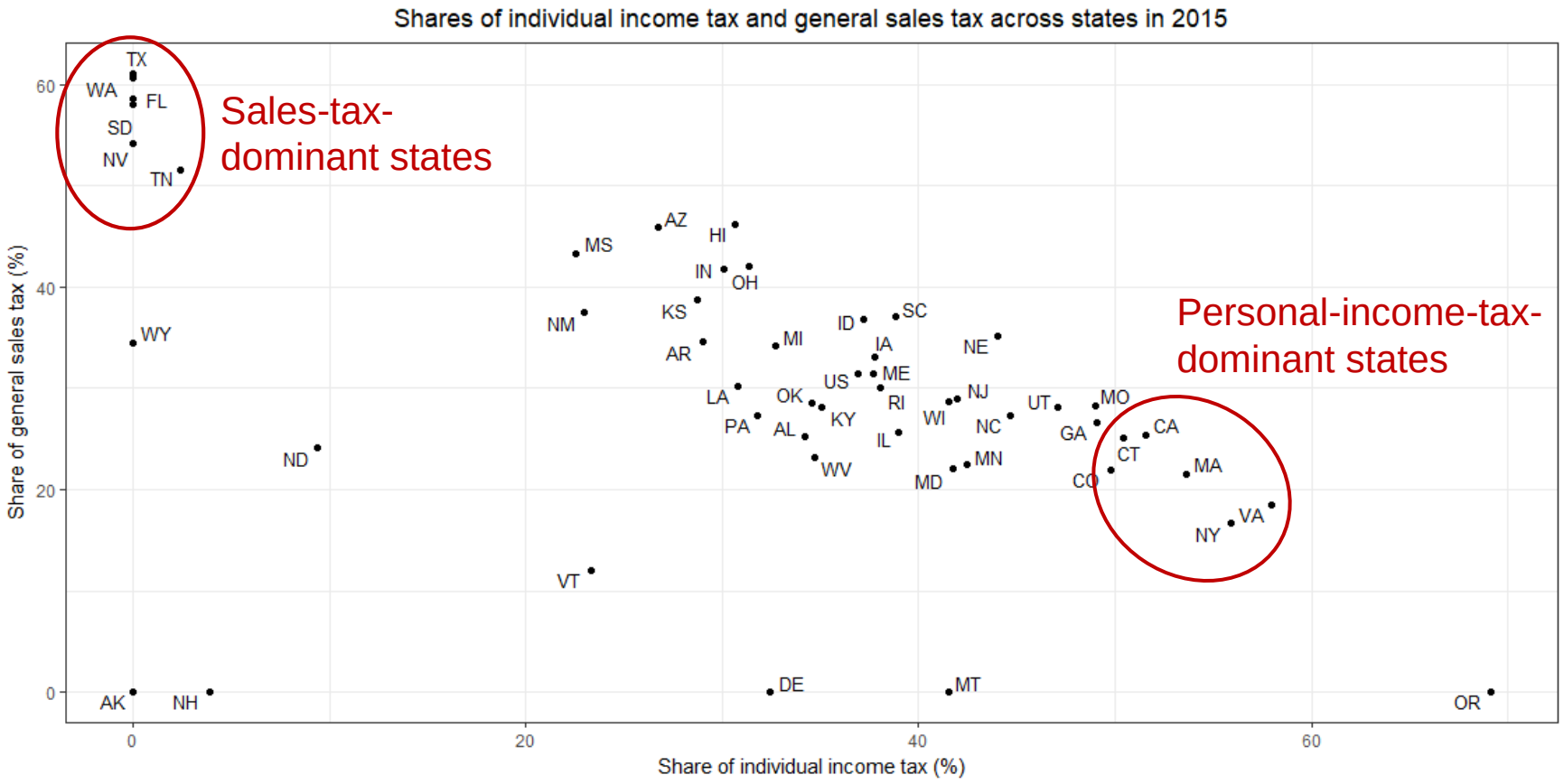
Assumptions about trend and cyclical growth rates of tax revenues for simulation analysis

		Growth rates in inflation-adjusted tax revenue			
		Individual income tax	General sales tax	Selective sales tax	Other taxes
Trend growth rate		1.9%	1.9%	1.9%	1.9%
Elasticity of cyclical change	Real GDP growth	1.0	1.2	0.5	1.3
	Real Stock returns	0.2	-	-	-

Constructing tax portfolios for stylized governments



Constructing tax portfolios for stylized governments



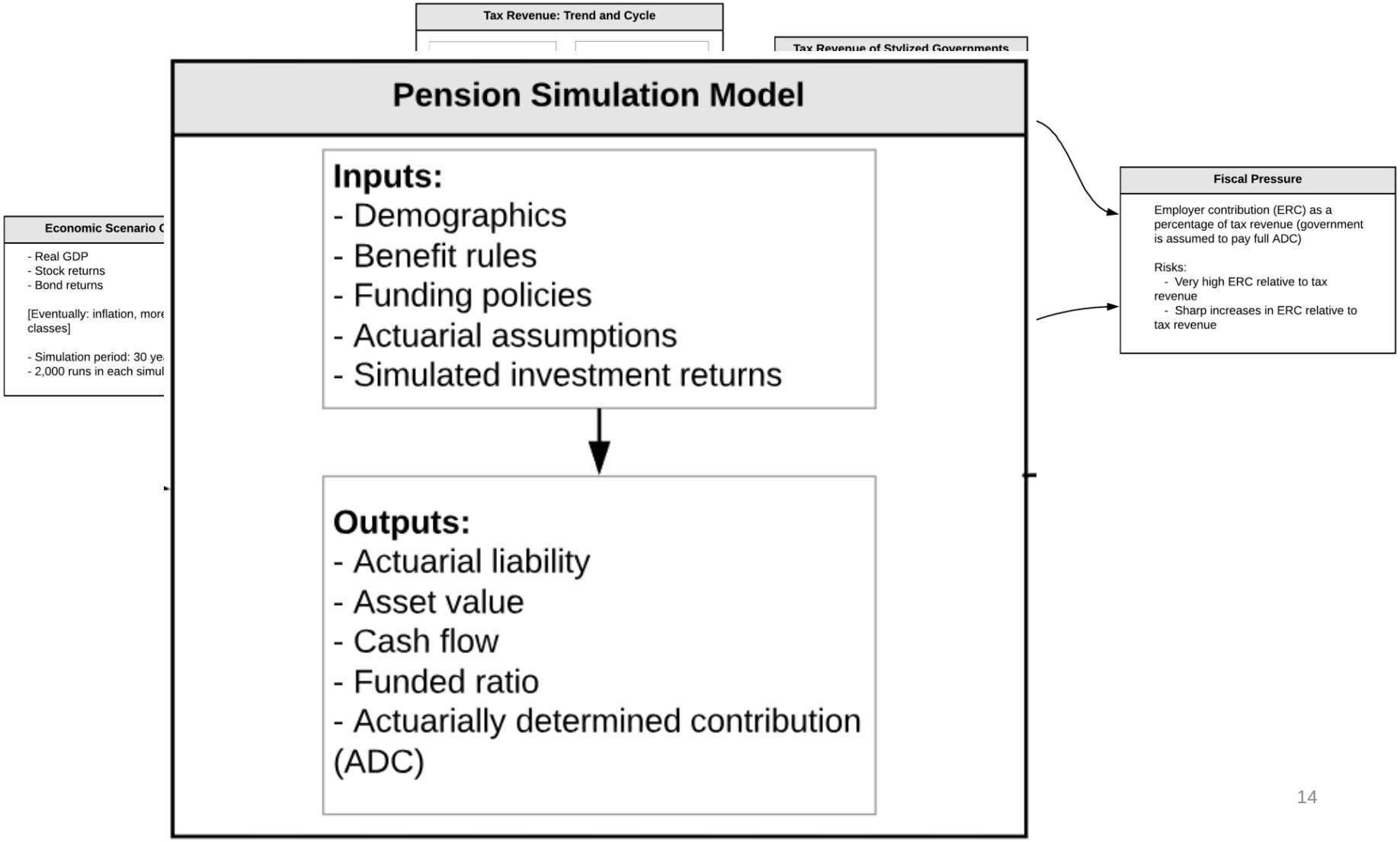
Tax portfolios for stylized governments

Tax revenue structure of stylized state governments

Each tax as a percentage of total tax revenue

	Personal income tax revenue	General sales tax revenue	Selective sales tax revenue	Other taxes	Total
Personal income tax dominant state	55%	20%	10%	15%	100%
Sales tax dominant state	0%	60%	25%	15%	100%

Pension simulation model



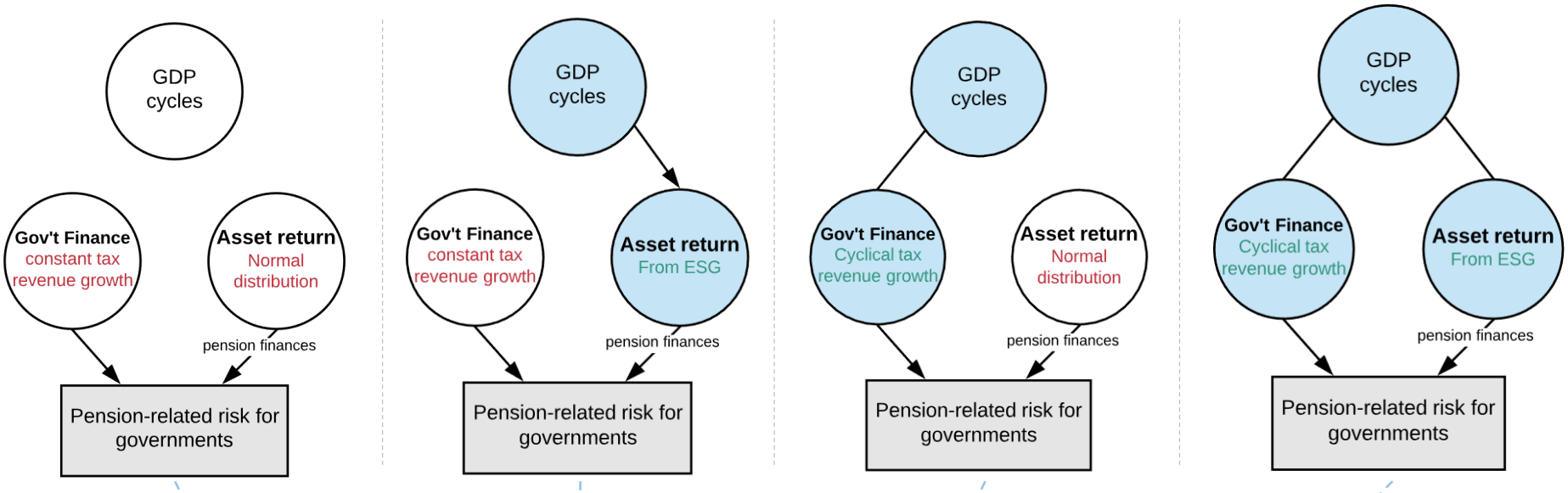
Potential compounding risks from business cycles, correlated investment returns, and tax revenue

- With tax revenues, asset returns, and pension finances that are all generated within a coherent simulation framework, we can examine the compounding of risks from correlated investment returns and tax revenues.

- Comparing stylized governments with a baseline model with no linkage and alternative model structures:
  - how pension-related risks can be understated if the linkage is ignored
  - how the increase in risk can be decomposed.

- Two types of risks

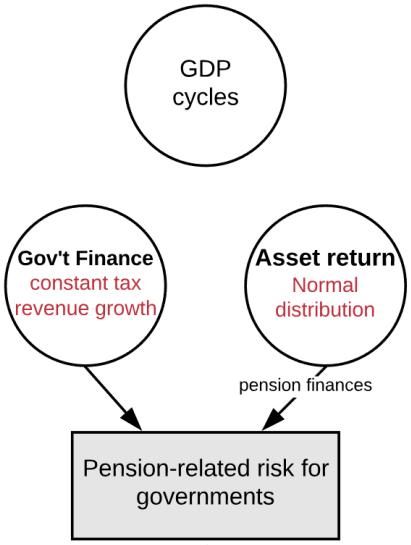
  1) The required employer contributions become **very high** relative to fiscal resources available to the sponsoring government
  2) The required employer **contributions rise sharply** in a short period of time

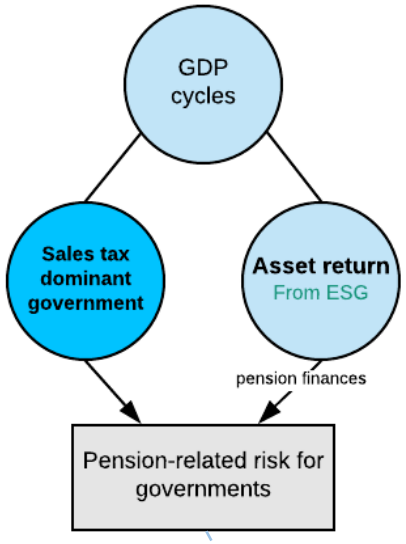


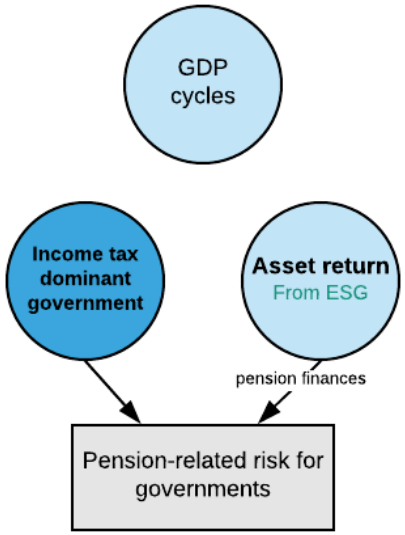
The risk of high employer contributions

Amortization method for unfunded liability	Probability of employer contribution as a percentage of total tax revenue being more than 5 percentage points above the year-1 level at any time during the 30-year simulation period					
	Constant growth of total tax revenue (equal to trend GDP growth)		Cyclical growth of total tax revenue (equal to trend + cycle GDP growth)		Stylized governments	
					Sales-tax-dominant state	Income-tax-dominant state
	Normally distributed returns	Simulated returns	Normally distributed returns	Simulated returns	Simulated returns	Simulated returns
	(1)	(2)	(3)	(4)	(5)	(6)
10-year open constant dollar	6.8%	9.2%	9.5%	17.8%	16.5%	22.8%
15-year open constant dollar	6.4%	8.9%	9.3%	17.2%	16.6%	22.8%
30-year open consant percent of payroll	1.3%	2.0%	4.9%	11.1%	10.1%	18.0%

Note: In year 1, employer contribution as a percentage of total tax revenue under the three amortization methods are 8.67% (10-year open constant dollar), 7.25% (15-year open constant dollar), and 5% (30-year open constant percent of payroll).







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Conclusion

- This paper shows how important it is to incorporate budgetary resources in pension fund risk analysis, and how that analysis can be deepened by modeling business cycles and investment returns together. Our work in this area is preliminary and can be extended and improved upon.

- The simulation results demonstrate that the pension-related risks are even larger than commonly understood under simple assumptions, and the risks can be further exacerbated by how state tax revenue structures respond to economic conditions.

- The choice of funding policies for public pension funds also has a significant impact on the risks that sponsoring governments face.

- Stress testing and risk reporting are, we hope, the wave of the future.

Appendix

Forward looking simulation parameters

Simulation parameters based on forward-looking assumptions

Parameter		Assumption on quarterly data (Annualized rates in parentheses except for the transition probabilities)		Target assumptions for annual data
		Expansion period	Recession period	
GDP growth (real)	Transition probability	4.8% (expansion to recession)	32% (recession to expansion)	
	Expected GDP growth	0.67% (2.7%)	-0.83% (-3.4%)	Target expected geometric mean of annual GDP growth is 1.9%.
	Standard deviation of GDP growth	0.74% (1.48%)	0.74% (1.48%)	
Stock return (nominal)	Expected return	2.54% (10.6%)	-2.05% (-8.5%)	Target expected geometric mean of annual stock return is 6.7%
	Standard deviation	6.9% (13.8%)	11.9% (23.8%)	Target standard deviation of stock return is 17%
Bond return (nominal)	Expected return	0.9% (3.6%)	0.9% (3.6%)	Target expected geometric mean of annual stock return is 3.6%
	Standard deviation	2% (4%)	2% (4%)	Target standard deviation of annual bond return is 4%
	Correlation between stock return and bond return	0.15		

Notes:

1. Adjustments are made to the quarterly parameters estimated with historical data to ensure the simulated results for annual data (converted from simulated quarterly data) are consistent with the target assumptions for annual data. The variables that have been adjusted and their historical-data based estimates (all for quarterly data) are expected GDP growth in expansion (0.95%), GDP growth in recession (-0.55%), expected stock return in expansion (3.2%), expected stock return in recession (-1.4%), expected bond return (1.6%), standard deviation of bond return (5.1%). (Historical bond returns are for long-term corporate bond)

3. The target annual GDP growth is obtained from the 30-year projection of potential growth GDP made by CBO (2017). The target assumptions on annual stock and bond returns are generally consistent with the capital market assumptions used in Mennis, et. al (2017).

Performance of our economic scenario generator

Summary statistics for historical and simulated data

	Historical value for 1953-2015 (63 years)	Median of the simulated distribution (2,000 simulations)	Historical value's percentile in the simulated distribution
Economic regimes			
Number of recessions	10	10	52
Number of expansions	10	11	40
Average length of recession (quarters)	3.7	3.0	79
Average length of expansion (quarters)	20.2	19.4	57
GDP growth			
Mean	3.0%	3.1%	38
Standard Deviation	2.5%	2.2%	91
Stock return			
Mean	10.4%	10.9%	40
Standard Deviation	15.7%	17.2%	19
Kurtosis (Measure of heavy-tailedness)	0.13	0.10	52
Bond return			
Mean	6.6%	6.6%	49
Standard Deviation	9.6%	10.6%	14
Kurtosis (Measure of heavy-tailedness)	0.63	-0.16	88

Note: The kurtosis measure compares the "heavy-tailedness" of our simulated distributions to the normal distribution. Values greater than 1 mean our distribution has heavier tails than the normal distribution, and less than 1 mean the opposite.

How we use model parameters to calculate tax revenue growth in the simulation

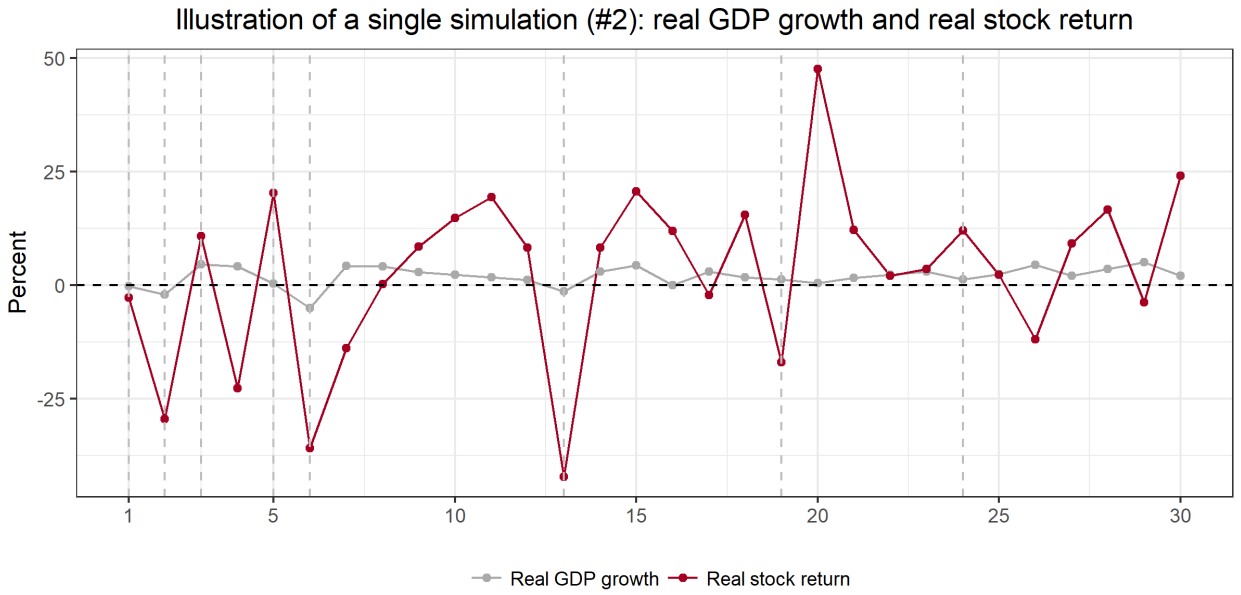
An example of the calculation of cyclical tax revenue growth in the simulation

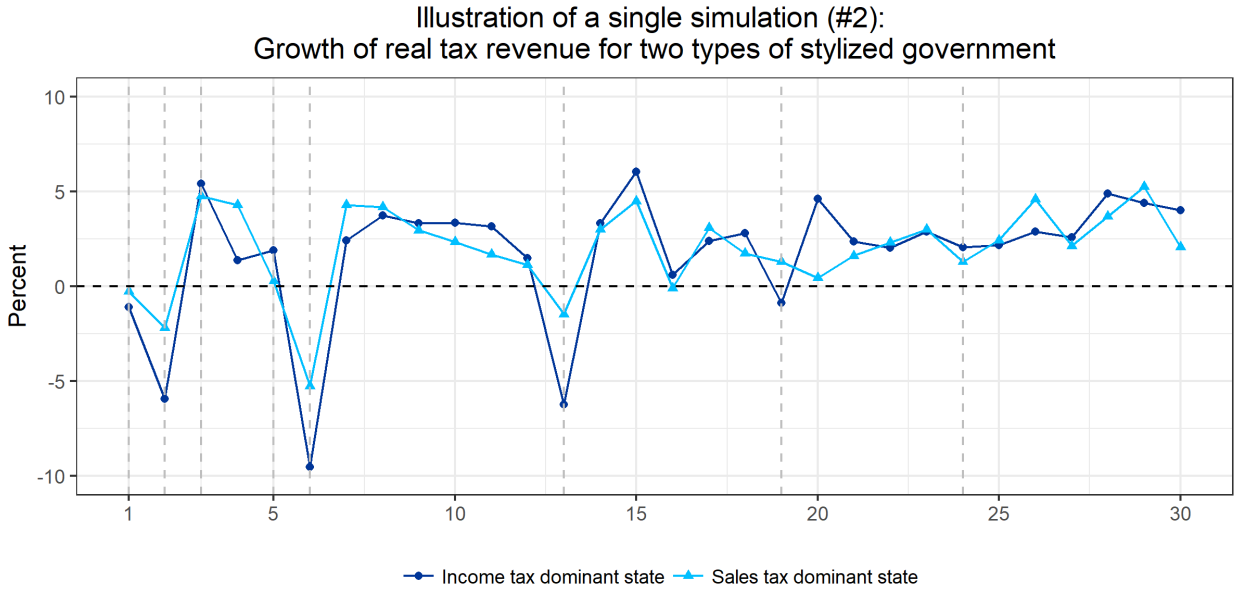
	Elasticity with respect to		Hypothetical Cyclical GDP growth (c)	Hypothetical Cyclical Stock return (d)	Cyclical tax revenue growth (a)×(c) + (b)×(d)
	Cyclical GDP growth (a)	Cyclical stock return (b)			
Individual income tax	1.0	0.2	1%	2%	1% × 1 + 2% × 0.2 = 1.4%
General sales tax	1.2	0	1%	2%	1% × 1.2 = 1.2%
Selective sales tax	0.5	0	1%	2%	1% × 0.5 = 1.2%
Other taxes	1.3	0	1%	2%	1% × 1.3 = 1.3%

Notes:

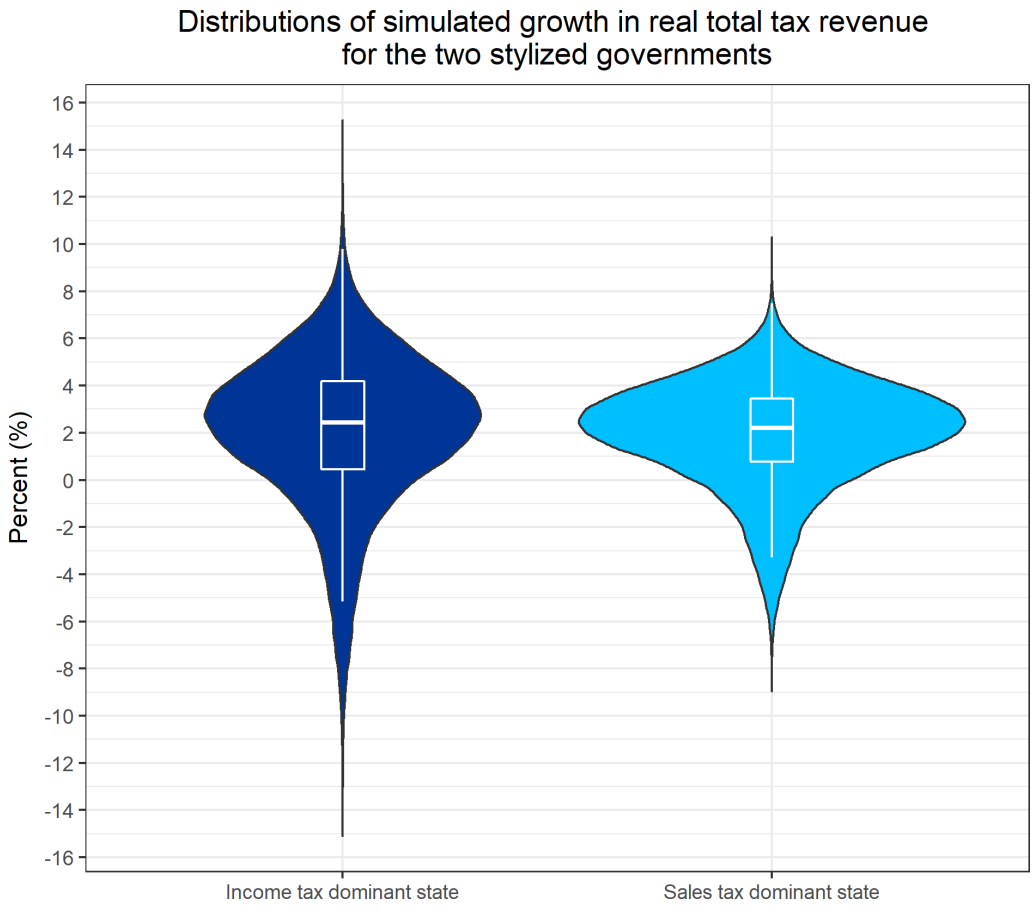
1. All rates are inflation-adjusted values.
2. Cyclical growth of GDP and stock return are defined as the difference between total growth rate and trend growth rate.
3. For each tax category, total tax revenue growth is the sum of the cyclical growth calculated in the table and the assumed trend growth (1.9% in the simulation).

Illustration of single simulation





Distribution of growth in real tax revenue



Risk of sharp increases in pension contributions relative to tax revenue

Risk of sharp increase in employer contribution relative to tax revenue under alternative funding policies

Amortization method for unfunded liability	Probability of employer contribution rising more than 3 percent of total tax revenue in any 2-year period during the 30-year simulation period					
	Constant growth of total tax revenue (equal to trend GDP growth)		Cyclical growth of total tax revenue (equal to trend + cycle GDP growth)		Stylized governments	
					Sales-tax-dominant state	Income-tax-dominant state
	Normally distributed returns	Simulated returns	Normally distributed returns	Simulated returns	Simulated returns	Simulated returns
	(1)	(2)	(3)	(4)	(5)	(6)
10-year open constant dollar	43.0%	44.1%	44.2%	48.7%	47.8%	54.7%
15-year open constant dollar	20.9%	23.7%	23.3%	31.4%	30.5%	37.8%
30-year open consant percent of payroll	0.5%	1.2%	1.1%	3.1%	2.5%	6.9%

Note: In year 1, employer contribution as a percentage of total tax revenue under the three amortization methods are 8.67% (10-year open constant dollar), 7.25% (15-year open constant dollar), and 5% (30-year open constant percent of payroll).

Risk of large contribution increases in a short period of time

- Contribution-smoothing policies cannot make risks go away: They transfer risks from governments to pension plans

	Risk of sharp increase in employer contribution relative to tax revenue*	Employer contribution as a % of tax revenue in year 1	Median Present value at year 1 of total employer contribution for year 1-15**	Median Present value at year 1 of total employer contribution for year 16-30**	Probability of low funded ratio***
10-year open constant dollar	48.7%	8.7%	1.32	0.64	7.1%
15-year open constant dollar	31.4%	7.3%	1.23	0.67	11.7%
30-year open contsant percent of payroll	3.1%	5.0%	1.00	0.68	30.9%

Notes:

* Probability of employer contribution rising more than 3 percent of total tax revenue in any 2-year period during the 30-year simulation period based on Model (4) (Cyclical growth of total tax revenue with simulated investment returns).

** The present value at year 1 of total employer contribution in year 1-15 under the policy "30-year open constant percent of payroll" is standardized to 1. All other values are standardized accordingly.

*** Probability of low funded ratio: the probability of funded ratio falling below 40% in any year during the 30 year simulation period.

Simulation Model Comparisons

Model	Description	Tax revenue linked to GDP?	Asset return linked to GDP?	Based on stylized government?	Tax revenue linked to asset return?
(1)	**Unlinked model:** - Constant growth of total tax revenue (equal to trend GDP growth). - Returns from normal distribution.	No	No	No	No
(2)	**Asset return linked only:** - Constant growth of total tax revenue (equal to trend + cycle GDP growth). - Returns from regime-switching simulation model.	No	Yes	No	No
(3)	**Tax revenue linked only:** - Cyclical growth of total tax revenue (equal to trend plus cycle GDP growth). - Returns from normal distribution.	Yes	No	No	No
(4)	**Both tax revenue and asset return linked:** - Cyclical growth of total tax revenue (equal to trend plus cycle GDP growth). - Returns from regime-switching simulation model.	Yes	Yes	No	No
(5)	**Stylized government: sales-tax-dominant state** - Cyclical growth of total tax revenue; estimated responsiveness to GDP growth. - Returns from regime-switching simulation model.	Yes	Yes	Yes	No
(6)	**Stylized government: income-tax-dominant state** - Cyclical growth of total tax revenue; estimated responsiveness to GDP growth and asset return. - Returns from regime-switching simulation model.	Yes	Yes	Yes	Yes