Tax Revenue Volatility

Nathan Seegert

University of Michigan

September 10, 2012
1. Tax revenue volatility increased dramatically in the 2000s.

2. Tax revenue volatility magnifies the consequences of government budget crises.

3. State tax policy led to the increase in volatility.
Volatile Tax Revenues and Government Budget Crises.

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“State governments have been on a fiscal rollercoaster in recent years.”
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Volatility Increased in Most States.

Percent Change (1950-1999) and (2000-2010).

In levels all states experienced increases in volatility. Alaska and Hawaii both experienced increases in volatility, not shown.


Difference percent innovations (1951 - 1999) and (2000 - 2010); ratio volatility (squared deviations from cubic time trend and AR1 process) and total tax revenue.
Revenue Volatility Leads to Expenditure Volatility

Tax revenue volatility Granger causes expenditure volatility.

1. States seem unable to smooth revenue shocks.
2. 49 states have balanced budget rules.
3. Rainy day funds seem unable to smooth revenues.

Cubic time trend with autoregressive process. US Census 1951 - 2010 state expenditures and state and local tax revenue. State tax revenue deviations from trend Granger cause state expenditure deviations from trend.
Expenditure Volatility is Costly.

1. Counter cyclical expenditure demands increase the costs associated with volatility.

2. Spending commitments cause a few items to absorb the volatility.

3. Expenditure volatility adds uncertainty to the economy.

California made an additional $1 billion of cuts midyear.

- School districts lose an additional $7 to $638 per student.
State Tax Revenue Volatility Beginning to get Attention.

1. “The fiscal challenges are enormous, widespread and, unfortunately, far from over.” - NCSL via Dadayan and Boyd, 2009


2. “It is difficult to find a comprehensive national source of data for all 50 states that would allow for complete exclusion of the effects of rate and base changes.”
   - Elizabeth C. McNichol commenting on Cornia and Nelson (2010)

▷ These papers document the increase in tax revenue volatility but lack data on tax rates.

3. I collect data from the Book of States to put together a panel data set of tax rates from 1951 - 2010.
Demonstrating the Importance of Tax Policy

1. Create theoretical model to
   ▶ Produce an equation for the volatility of tax revenue to estimate
     ▶ Tax policy, business cycles, tax base
     ▶ Determine how governments should tax volatile tax bases.

2. Empirically decompose tax revenue volatility to determine the relative importance of tax policy, business cycles, and tax base factors in explaining the increase in tax revenue volatility.
   ▶ Tax policy explains 70% of the increase in tax revenue volatility.

3. Produce a condition for optimal taxation with volatile tax bases.
   ▶ Estimate this condition for each state to determine if they rely too heavily on income or sales taxes.
The goal of the model is twofold:

1. Produces an equation for tax revenue volatility to estimate

2. Setup normative model to determine how governments should tax volatile tax bases.
   - Trade off deadweight loss and volatility.
## Timing in the Model

### Order of Decisions

<table>
<thead>
<tr>
<th>Order</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>Government</td>
</tr>
<tr>
<td>2nd</td>
<td>Nature</td>
</tr>
<tr>
<td>3rd</td>
<td>Individual</td>
</tr>
<tr>
<td>4th</td>
<td>Production occurs</td>
</tr>
<tr>
<td>5th</td>
<td>Utility realized</td>
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</table>

### Choices

<table>
<thead>
<tr>
<th>Choice</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tau_s, \tau_w$</td>
<td>Tax rates</td>
</tr>
<tr>
<td>$\theta$</td>
<td>Production state</td>
</tr>
<tr>
<td>$c, \beta, L$</td>
<td>Consumption $c, \beta$, labor supply $L$</td>
</tr>
</tbody>
</table>
Production Function:

\[ X_t(L_t, \theta_t) = \theta_t L_t^\gamma \]

1. \( X_t \) Intermediate good costlessly transformed into public and private consumption.

2. Production state \( \theta_t \sim \text{Log} - \mathcal{N}(\mu_\theta, \sigma_\theta^2) \)

3. \( L_t \) labor, elastically supplied by representative individual.

4. Wages and profits assumed to be not perfectly correlated.
Individual Behavior

\[
\max_{c_t, L_t, \beta_t} \quad u_t = U(c_t, \beta_t, L_t, g_t)
\]

subject to

\[
c_t = (1 - \tau_{s,t} \beta_t) \left[ (1 - \tau_{w,t}) w_t L_t + \pi_t \right]
\]

Net Income $y_t$

- Elastic labor supply $L_t$ and utility public good $g_t$.
- Total consumption split, taxed and untaxed goods.
  - $c_1 \equiv \beta_t c_t$ taxed and $c_2 \equiv (1 - \beta_t) c_t$ untaxed.
  - $\beta_t$ choice variable captures behavioral responses.
- Profit $\pi_t$.
  - Profit and wage income not perfectly correlated.
  - Consumption and wage income not perfectly correlated.
Individual Behavior

$$\max_{c_t, L_t, \beta_t} \quad u_t = U(c_t, \beta_t, L_t, g_t)$$

subject to

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Individual Behavior

$$\max_{c_t, L_t, \beta_t} u_t = U(c_t, \beta_t, L_t, g_t)$$

subject to

$$c_t = (1 - \tau_s, t \beta_t)[(1 - \tau_w, t) w_t L_t + \pi_t]$$

Net Income $y_t$

- Elastic labor supply $L_t$ and utility public good $g_t$.

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Government

\[ \max_{\tau_s, \tau_w} E[u] = \int u \Phi(\theta) \equiv M(c_t, \sigma_{c,t}^2, \beta_t, L_t) + G(R_t, \sigma_{R,t}^2) \]

subject to

\[ g_t = R_t = \tau_w L_t w_t + \tau_s \beta_t y_t \]

\[ \sigma_{R,t}^2 = \tau_w^2 L_t^2 \sigma_{w,t}^2 + \tau_s^2 \beta_t^2 \sigma_{y,t}^2 + 2 \tau_w \tau_s \beta_t L_t \sigma_{y,w,t} \]

Assumed public and private consumption are additively separable

\[ M(c_t, \sigma_{y,t}^2, \beta_t, L_t) + G(R_t, \sigma_{R,t}^2). \]
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\[
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subject to

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g_t = R_t = \tau_w L_t w_t + \tau_s \beta_y t
\]

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\]

Example

Assumed public and private consumption are additively separable

\[
M(c_t, \sigma_{y,t}^2, \beta_t, L_t) + G(R_t, \sigma_{R,t}^2).
\]
Data: Tax Rates Brackets and State Economic Variables

Tax Rates, Brackets (1951-2010), and Tax Revenue (1963 - 2010)

- Book of States
- Cross-checked with
  - Tax Foundation
  - World Tax Database
  - Advisory Commission on Intergovernmental Relations (ACIR)
  - U.S. Census of Governments.

Economic Variables; State GDP, Personal Income, Population

- U.S. Bureau of Economic Analysis
- U.S. Census

- 3000 state-year observations, 1108 tax rate changes.
130 increases and 128 decreases however, average tax rate increases from 3.15 to 4.81 from (1951 - 1999) to (2000 - 2010).
1. Model produced an equation of tax revenue volatility.

\[ \sigma^2_{R,t} = \tau^2_w L^2_t \sigma^2_{w,t} + \tau^2_s \beta^2 \sigma^2_{y,t} + 2\tau_w \tau_s \beta L_t \sigma_{y,w,t} \]

2. Decompose volatility to determine the relative importance of tax policy, business cycles, and tax base changes in explaining the increase in tax revenue volatility.

\[ \Delta_i = \sigma_{R_i,t|\text{After}} - \sigma_{R_i,t|\text{Before}} \]

3. Decomposition similar to Oaxaca (1971), Blinder (1971), and Dinardo, Fortin, and Lemieux (1996).
Two Step Decomposition of Tax Revenue

Step One: Decompose aggregate tax revenue into its parts.

\[ \sigma_{R,t}^2 = \tau_w^2 L_t^2 \sigma_{w,t}^2 + \tau_s^2 \beta_t^2 \sigma_{y,t}^2 + 2\tau_w \tau_s \beta_t L_t \sigma_{y,w,t} \]

Step Two: Decompose specific tax revenue into its parts.

\[ \log(\sigma_{R,t}^2) = \log(\tau_s^2) + \log(\beta_t^2) + \log(\sigma_{y,t}^2) \]

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Two Step Decomposition of Tax Revenue

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- Tax Policy
- Tax Base
- Business Cycle
Coefficients Capture The Tax Base.

\[ \log(\sigma^2_{R_s,t}) = \log(\tau^2_s) + \log(\beta^2_t) + \log(\sigma^2_{y,t}) \]

Tax base is a function of tax and business cycle factors.

\[ \log(\beta_t) = \delta_0 + \log(\tau)\psi_1 + \log(x)\psi_2 + \nu \]

Tax Policy    Business Cycle    Unobservables

Empirical model of consumption tax revenue volatility.

\[ \log(\sigma^2_{R_s,t}) = \delta_0 + \log(\tau)\delta_1 + \log(x)\delta_2 + \varepsilon \]

- The coefficients capture the tax base \( \delta_1(\tau_s) = 2(1 + \psi_1) \).
- Changes in the coefficients represent changes in the tax base.
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Δs in Volatility Explained by Δs in Variables or Coefficients

\[ \Delta_i = \log(\sigma_{R_i,t|\text{After}}) - \log(\sigma_{R_i,t|\text{Before}}) \]

After
\[ \log(\sigma_{R_i,t|\text{After}}) = \gamma_0 + x|_{\text{After}} \gamma_1 + \tau|_{\text{After}} \gamma_2 + \eta_{state} \]

Before
\[ \log(\sigma_{R_i,t|\text{Before}}) = \phi_0 + x|_{\text{Before}} \phi_1 + \tau|_{\text{Before}} \phi_2 + \eta_{state} \]

1. Changes in coefficients capture changes in tax base.
2. Changes in \(x\) capture changes in business cycles.
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$$\Delta_i = \log(\sigma_{R_i,t|\text{After}}) - \log(\sigma_{R_i,t|\text{Before}})$$

After

$$\log(\sigma_{R_i,t|\text{After}}) = \gamma_0 + x_{\text{After}}\gamma_1 + \tau_{\text{After}}\gamma_2 + \eta_{\text{state}}$$

Before

$$\log(\sigma_{R_i,t|\text{Before}}) = \phi_0 + x_{\text{Before}}\phi_1 + \tau_{\text{Before}}\phi_2 + \eta_{\text{state}}$$

1. Changes in coefficients capture changes in tax base.
2. Changes in $x$ capture changes in business cycles.
3. Changes in $\tau$ capture changes in tax policy.
\( \Delta s \) in Volatility Explained by \( \Delta s \) in Variables or Coefficients

\[
\log(\sigma_{R_i,t}) = \delta_0 + x\delta_1 + \tau\delta_2 + (\eta_{After} \times x)\delta_3 + (\eta_{After} \times \tau)\delta_4 + \eta_{After} + \eta_{state}
\]

After
\[
\log(\sigma_{R_i,t|After}) = \gamma_0 + x|_{After}\gamma_1 + \tau|_{After}\gamma_2 + \eta_{state}
\]

Before
\[
\log(\sigma_{R_i,t|Before}) = \phi_0 + x|_{Before}\phi_1 + \tau|_{Before}\phi_2 + \eta_{state}
\]

1. Changes in coefficients capture changes in tax base.
2. Changes in \( x \) capture changes in business cycles.
3. Changes in \( \tau \) capture changes in tax policy.

where \( \eta_{After} \) is an indicator After years, \( \delta_3 = \gamma_1 - \phi_1 \), \( \delta_4 = \gamma_2 - \phi_2 \).
Δs in Volatility Explained by Δs in Variables or Coefficients

\[
\log(\sigma_{R_i,t}) = \delta_0 + x\delta_1 + \tau \delta_2 + (\eta_{After} \times x)\delta_3 + (\eta_{After} \times \tau)\delta_4 + \eta_{After} + \eta_{state}
\]

After

\[
\log(\sigma_{R_i,t|After}) = \gamma_0 + x_{|After}\gamma_1 + \tau_{|After}\gamma_2 + \eta_{state}
\]

Before

\[
\log(\sigma_{R_i,t|Before}) = \phi_0 + x_{|Before}\phi_1 + \tau_{|Before}\phi_2 + \eta_{state}
\]

\[\Delta_i = \]

1. Tax Base

\[= \eta_{|After} + \delta_3 x_{|After} + \delta_4 \tau_{|After}\]

2. Business Cycle

\[+ \delta_1(x_{|After} - x_{|Before})\]

3. Tax Policy

\[+ \delta_2(\tau_{|After} - \tau_{|Before})\]

where \(\eta_{After}\) is an indicator After years, \(\delta_3 = \gamma_1 - \phi_1\), \(\delta_4 = \gamma_2 - \phi_2\).
Tax Factors are an Important Explanation of Volatility.

\[ \Delta_A = (\bar{\tau}_{\text{After}} - \bar{\tau}_{\text{Before}})\hat{\delta}_2 + (\bar{x}_{\text{After}} - \bar{x}_{\text{Before}})\hat{\delta}_1 + \eta_{\text{After}} + \bar{x}_{\text{After}}\hat{\delta}_3 + \bar{\tau}_{\text{After}}\hat{\delta}_4 \]

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<thead>
<tr>
<th>Factor</th>
<th>Percent Explain</th>
<th>95% CI</th>
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<tbody>
<tr>
<td>Tax Policy</td>
<td>70.26 %</td>
<td>[58.42, 88.49]</td>
</tr>
<tr>
<td>Business Cycle</td>
<td>28.95 %</td>
<td>[10.69, 40.69]</td>
</tr>
<tr>
<td>Tax Base</td>
<td>0.783 %</td>
<td>[0.7002, 0.8686]</td>
</tr>
</tbody>
</table>

State FE: Yes
Observations: 2400

Bootstrapped 95 percentile confidence interval (3000 replications), clustered by state.
Base Case: cubic time trend and kernel matching to produce weights.
Tax Factors are an Important Explanation of Volatility.

\[ \hat{\Delta}_A = \hat{\Delta}_I + \hat{\Delta}_S + \hat{\Delta}_\Pi + \hat{\Delta}_{I,S} + \hat{\Delta}_{I,\Pi} + \hat{\Delta}_{S,\Pi} \]

(52%) + (20%) + (14%) + (7%) + (4%) + (3%)%

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(52%) (20%) (14%) (7%) (4%) (3%)

<table>
<thead>
<tr>
<th>Percent Explain</th>
<th>Income (I)</th>
<th>Sales (S)</th>
<th>Corporate ((\Pi))</th>
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<td>70.26 %</td>
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<td>52.08 %</td>
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<td>[58.42, 88.49]</td>
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<td>84.14 %</td>
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<tr>
<td><strong>Business Cycle</strong></td>
<td>28.95 %</td>
<td>33.04 %</td>
<td>47.35 %</td>
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<td>[10.69, 40.69]</td>
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<td>15.04 %</td>
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<td>0.78 %</td>
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<td>[0.70, 0.87]</td>
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<td>0.82 %</td>
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Bootstrapped 95 percentile confidence interval (3000 replications) clustered by state.
Base Case: cubic time trend and kernel matching to produce weights.
Volatility of revenue and economic variables calculated as \((x - x_{time\ trend})^2\).

Robustness ▶️ Causality ▶️ Overlap ▶️ Weighted Regression ▶️ Index
Identifying assumption

**Identifying Assumption:** The conditional mean of the error structure is equal to zero, \( E[\epsilon | x, \tau, D, \eta_{\text{state}}] = 0 \).

Limitations of the model

1. State-year shock to tax revenue volatility.
   - State fixed effects capture time invariant state differences.
   - State neighbor-year fixed effects capture “regional” shocks.
   - Replace tax rate with two year lagged values as a check.
   - Tax Lags Robustness

2. Omitted tax policy factors specifically base changes.
   - Tax brackets omitted to test for omitted variable bias potential.
   - Omitted Variable Bias Robustness
Determine How Governments *Should* Tax Volatile Bases.

1. Government’s optimization determines optimal mix of taxes.

2. Government trades off volatility and deadweight loss.

3. Volatility includes:
   
   - Risk-sharing between public and private consumption
   - Hedging risk between tax bases.

4. Estimate optimal taxation rule to determine whether states relying too heavily on income or sales taxes.
Government

\[
\max_{\tau_s, \tau_w} E[u] = \int u\Phi(\theta) \equiv M(c_t, \sigma_c^2, \beta, L_t) + G(R_t, \sigma_R^2)
\]

subject to

\[
g_t = R_t = \tau_w L_t w_t(\theta) + \tau_s \beta_t y_t(\theta)
\]

Both of the government’s tax bases are state-dependent, meaning that conventional approaches to evaluating alternative tax structures (e.g. deadweight loss for equal revenue streams) encounter complications because differing tax structures will change the pattern of returns across states of nature.

Example

Assumed public and private consumption are additively separable

\[
M(c, \sigma_c, \beta) + G(R, \sigma_R).
\]
Volatility Adjusted Ramsey Rule

1. Necessary optimal tax policy condition; balanced portfolio income and consumption taxation.

\[
\omega_B \varepsilon_{B, \tau_s} + \omega_\sigma \varepsilon_{\sigma, \tau_s} = \omega_B \varepsilon_{B, \tau_w} + \omega_\sigma \varepsilon_{\sigma, \tau_w}
\]

Deadweight loss + Volatility = Deadweight loss + Volatility

2. Governments trade off deadweight loss and costs from volatility.

3. Sufficient condition for imbalance.

\[
\varepsilon_{B, \tau_i} > \varepsilon_{B, \tau_j} \quad \& \quad \varepsilon_{\sigma, \tau_i} > \varepsilon_{\sigma, \tau_j}
\]

\[
\omega_B = -M_3 \beta/R \text{ and } \omega_G = -\sigma_R^2 G_2/R
\]
Estimating Volatility-Adjusted Ramsey Rule

1. Four estimations for each state, seemingly unrelated regression.

\[ \varepsilon_{\sigma,\tau_i} : \log(\sigma_{R_i,t}^2) = \delta_0 + \log(\tau)\delta_1 + \log(\sigma_x)\delta_2 + \varepsilon_{i,t} \]

\[ \varepsilon_{B,\tau_i} : \log(R_{i,t}) = \delta_0 + \log(\tau)\delta_1 + \log(x)\delta_2 + u_{i,t} \]

2. All state data used by using inverse probability weighting.

\text{Probit } \eta_{state} \ log(\tau)\delta_1 + \log(x)\delta_2

3. Time varying elasticities calculated from estimates.

\[ \varepsilon_{\sigma,\tau_i,t} = \hat{\varepsilon}_{\sigma,\tau_i} \frac{\bar{\tau}_i}{\sigma_{R_i,t}^2} \frac{\sigma_{R_i,t}^2}{\tau_{i,t}} \]

\[ \varepsilon_{B,\tau_i} = \hat{\varepsilon}_{B,\tau_i} \frac{\bar{\tau}_i}{R_i} \frac{R_{i,t}}{\tau_{i,t}} \]
26 states imbalanced and 14 overweight the income tax. Based on estimates of $\varepsilon_{B,\tau_s}, \varepsilon_{B,\tau_w}, \varepsilon_{\sigma,\tau_s}, \varepsilon_{\sigma,\tau_w}$, for each state.

Hawaii balanced, not shown.
Estimates of elasticity of base and volatility with respect to tax rate for each state for the sufficient condition.
AK and NH do not have an income or sales tax (AK local sales 7%)
States without sales tax; DE, MT (3% local), OR (5% local). States without income tax; FL, NV, SD, TN, TX, WA, WY.
36 states imbalanced and 26 overweight the income tax. Based on estimates of $\varepsilon_B, \tau_s, \varepsilon_B, \tau_w, \varepsilon_{\sigma}, \tau_s, \varepsilon_{\sigma}, \tau_w$, for each state.

Hawaii balanced, not shown.
Estimates of elasticity of base and volatility with respect to tax rate for each state for the sufficient condition.
AK and NH do not have an income or sales tax (AK local sales 7%)
States without sales tax; DE, MT (3% local), OR (5% local). States without income tax; FL, NV, SD, TN, TX, WA, WY.
Volatility Matters and Tax Policy Can Provide Stability

1. Empirically, tax policy explains 70% of the increase in volatility state governments experienced.

2. Theoretically, optimal tax policy depends on costs of volatility.
   ▶ Volatility-adjusted Ramsey rule.

3. Practically, the cost of volatility to state governments is large.
   ▶ Federal government should decrease (or at least not increase) volatility at the state level.

4. Additional work demonstrates the importance of considering tax revenue volatility.
   ▶ Volatility is of first-order importance in contrast to deadweight loss which is second-order.
Thank you.
Production Function: \( X_t(L_t, \theta_t) = \theta_t L_t^\gamma \)

1. \( X_t \) Intermediate good costlessly transformed into public and private consumption.

2. Technology Shock: \( \theta_t = \mu_t + \nu_t \)

3. \( L_t \) labor, elastically supplied by representative individual.

4. Wages and profits not perfectly correlated.

5. Wage: \( w(\theta_{w,t}) = \gamma \theta_{w,t} L_t^{\gamma - 1} \)  
   Profit: \( \Pi_t = (1 - \gamma) \theta_{\pi,t} L_t^\gamma \)
   
   a. \( \omega \) determines correlation between wages and profits.
   
   b. Wage: \( \theta_{w,t} = \mu_t + \omega \nu_t \)  
      Profit: \( \theta_{\pi,t} = \mu_t + \frac{1 - \gamma \omega}{1 - \gamma} \nu_t \)
   
   c. \( \mu_t = \phi \mu_{t-1} + (1 - \phi) \bar{\mu} + u_t \)  
      \( u_t \sim L.N(\mu_u, \sigma_u^2) \)  
      \( \nu_t \sim L.N(\mu_v, \sigma_v^2) \)
   
   d. \( \omega \) captures empirical fact wages and profits not perfectly correlated (sticky wages, bargaining, search).
Δs in Volatility Explained by Δs in Variables or Coefficients

\[
\log(\sigma_{R_i,t}) = \delta_0 + x\delta_1 + \tau\delta_2 + (\eta_{After} \times x)\delta_3 + (\eta_{After} \times \tau)\delta_4 + \eta_{After} + \eta_{state}
\]

After

\[
\log(\sigma_{R_i,t}|_{After}) = \gamma_0 + x|_{After}\gamma_1 + \tau|_{After}\gamma_2 + \eta_{state}
\]

Before

\[
\log(\sigma_{R_i,t}|_{Before}) = \phi_0 + x|_{Before}\phi_1 + \tau|_{Before}\phi_2 + \eta_{state}
\]

\[
\log(\sigma_{R_i,t}|_{After}) - \log(\sigma_{R_i,t}|_{Before}) = \gamma_0 - \phi_0
\]

\[
+ x|_{After}\gamma_1 - x|_{Before}\phi_1
\]

\[
+ \tau|_{After}\gamma_2 - \tau|_{Before}\phi_2
\]

where \(\eta_1\) is an indicator After years, \(\delta_3 = \gamma_1 - \phi_1\), \(\delta_4 = \gamma_2 - \phi_2\).
\[ \log(\sigma_{R_i,t}) = \delta_0 + x\delta_1 + \tau\delta_2 + (\eta_{After} \times x)\delta_3 + (\eta_{After} \times \tau)\delta_4 + \eta_{After} + \eta_{state} \]

After
\[ \log(\sigma_{R_i,t|After}) = \gamma_0 + x|_{After}\gamma_1 + \tau|_{After}\gamma_2 + \eta_{state} \]

Before
\[ \log(\sigma_{R_i,t|Before}) = \phi_0 + x|_{Before}\phi_1 + \tau|_{Before}\phi_2 + \eta_{state} \]

\[ \log(\sigma_{R_i,t|After}) - \log(\sigma_{R_i,t|Before}) = \gamma_0 - \phi_0 \]

\[ + x|_{After}\phi_1 - x|_{After}\phi_1 + x|_{After}\gamma_1 - x|_{Before}\phi_1 \]

\[ + \tau|_{After}\phi_2 - \tau|_{After}\phi_2 + \tau|_{After}\gamma_2 - \tau|_{Before}\phi_2 \]

where \( \eta_1 \) is an indicator After years, \( \delta_3 = \gamma_1 - \phi_1 \), \( \delta_4 = \gamma_2 - \phi_2 \).
Δs in Volatility Explained by Δs in Variables or Coefficients

\[
\log(\sigma_{R_i,t}) = \delta_0 + x\delta_1 + \tau\delta_2 + (\eta_{\text{After}} \times x)\delta_3 + (\eta_{\text{After}} \times \tau)\delta_4 + \eta_{\text{After}} + \eta_{\text{state}}
\]

The above model nests

\[
\text{After} \quad \log(\sigma_{R_i,t} | \text{After}) = \gamma_0 + x | \text{After} \gamma_1 + \tau | \text{After} \gamma_2 + \eta_{\text{state}}
\]

\[
\text{Before} \quad \log(\sigma_{R_i,t} | \text{Before}) = \phi_0 + x | \text{Before} \phi_1 + \tau | \text{Before} \phi_2 + \eta_{\text{state}}
\]

\[
\log(\sigma_{R_i,t} | \text{After}) - \log(\sigma_{R_i,t} | \text{Before}) = \gamma_0 - \phi_0
\]

\[
\underbrace{\gamma_1 - \phi_1}_{\delta_3} x | \text{After} + \phi_1(x | \text{After} - x | \text{Before})
\]

\[
\underbrace{\gamma_2 - \phi_2}_{\delta_4} \tau | \text{After} + \phi_2(\tau | \text{After} - \tau | \text{Before})
\]
$\Delta$s in Volatility Explained by $\Delta$s in Variables or Coefficients

$log(\sigma_{R_i,t}) = \delta_0 + x\delta_1 + \tau\delta_2 + (\eta_{\text{After}} \ast x)\delta_3 + (\eta_{\text{After}} \ast \tau)\delta_4 + \eta_{\text{After}} + \eta_{\text{state}}$

After
$log(\sigma_{R_i,t|\text{After}}) = \gamma_0 + x_{\text{After}}\gamma_1 + \tau_{\text{After}}\gamma_2 + \eta_{\text{state}}$

Before
$log(\sigma_{R_i,t|\text{Before}}) = \phi_0 + x_{\text{Before}}\phi_1 + \tau_{\text{Before}}\phi_2 + \eta_{\text{state}}$

$log(\sigma_{R_i,t|\text{After}}) - log(\sigma_{R_i,t|\text{Before}}) = \eta_{\text{After}} + \delta_3 x_{\text{After}} + \delta_4 \tau_{\text{After}}$

$\quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \qu
\[ \log(\sigma_{R_i,t}) = \delta_0 + x\delta_1 + \tau\delta_2 + (\eta_{After} \ast x)\delta_3 + (\eta_{After} \ast \tau)\delta_4 + \eta_{After} + \eta_{state} \]

After
\[ \log(\sigma_{R_i,t \mid After}) = \gamma_0 + x_{|After}\gamma_1 + \tau_{|After}\gamma_2 + \eta_{state} \]

Before
\[ \log(\sigma_{R_i,t \mid Before}) = \phi_0 + x_{|Before}\phi_1 + \tau_{|Before}\phi_2 + \eta_{state} \]

\[ \log(\sigma_{R_i,t \mid After}) - \log(\sigma_{R_i,t \mid Before}) = \]

1. Tax Base
\[ \eta_{|After} + \delta_3 x_{|After} + \delta_4 \tau_{|After} \]

2. Business Cycle
\[ + \delta_1 (x_{|After} - x_{|Before}) \]

3. Tax Policy
\[ + \delta_2 (\tau_{|After} - \tau_{|Before}) \]

where \( \eta_{After} \) is an indicator After years, \( \delta_3 = \gamma_1 - \phi_1, \delta_4 = \gamma_2 - \phi_2. \)
State Tax Revenue Became More Volatile In The 2000s.
State Tax Revenue Became More Volatile In The 2000s.

Empirical Puzzle
Increased Volatility in Terms of Deviations From Trend.

Cubic time trend with autoregressive process.
Data: US Census 1951 - 2010 total tax revenue.
Volatility Increased Per Person.

Cubic time trend with autoregressive process.

Data: US Census 1951 - 2010 total tax revenue.

Note: per person not per taxpayer and averaged across states.
Volatility Increased Despite Diverging Revenues.

1. Aggregating state revenues smooth idiosyncratic shocks.

2. Coefficient of variation across states within year measures state divergence.

3. State tax revenues diverge in 2000s working against increased aggregate volatility.

Coefficient of variation, ratio of standard deviation and mean, across states. Smoothed using a moving average with 7 year window on either side. Data: US Census 1951 - 2010 income, sales, and corporate tax revenue. Total tax revenue (not shown) diverge in 2000s as well.

1952 State and Local Tax Collections
- Property: 45%
- General Sales: 13%
- Select Sales: 20%
- Other: 13%
- Corporate Income: 4%
- Personal Income: 5%

2008 State and Local Tax Collections
- Property: 31%
- General Sales: 23%
- Select Sales: 11%
- Corporate Income: 4%
- Personal Income: 23%
- Other: 8%
1. Volatility defined as squared deviation from trend $\bar{R}$.

\[ \sigma_{R_i,t}^2 = (R_{i,t} - \bar{R}_i)^2 \]

2. A cubic time trend is used as the baseline.
   Estimated for all revenue and economic variables separately.
   Estimated for each state separately.
   Results are robust to different time trends
   HP Filter, Cubic with AR1

3. Estimation equations are stationary.
   Dickey-Fuller test rejects the null of a random walk.
Empirical Model Reweighting. 1/2

Actual Distribution

$$f_1^1(\log(\tilde{\sigma}_{R,i,t})) \equiv \int f^1(\log(\tilde{\sigma}_{R,i,t})|z)h(z|D = 1)dz$$

Counterfactual Distribution

$$f_0^1(\log(\tilde{\sigma}_{R,i,t})) \equiv \int f^1(\log(\tilde{\sigma}_{R,i,t})|z)h(z|D = 0)dz$$

Counterfactual distribution can be written as a weighted function of the actual distribution.

$$f_0^1(\log(\tilde{\sigma}_{R,i,t})) \equiv \int \omega f^1(\log(\tilde{\sigma}_{R,i,t})|z)h(z|D = 1)dz$$

By Bayes’ rule

$$\omega = P(D = 1|z)/P(D = 0|z))(P(D = 1)/P(D = 0))$$
Reweighting Decomposition. 2/2

Tax Base
\[
\int \log(\tilde{\sigma}_{R,i,t}) f^1(\log(\tilde{\sigma}_{R,i,t})|z) h(z|D = 1) \, dz
\]
\[
- \int \omega \log(\tilde{\sigma}_{R,i,t}) f^1(\log(\tilde{\sigma}_{R,i,t})|z) h(z|D = 1) \, dz
\]

Business Cycle
\[
\int \omega \log(\tilde{\sigma}_{R,i,t}) f^1(\log(\tilde{\sigma}_{R,i,t})|z) h(z|D = 1) \, dz
\]
\[
- \int \omega_x \log(\tilde{\sigma}_{R,i,t}) f^1(\log(\tilde{\sigma}_{R,i,t})|z) h(z|D = 1) \, dz
\]

Tax Policy
\[
\int \omega \log(\tilde{\sigma}_{R,i,t}) f^1(\log(\tilde{\sigma}_{R,i,t})|z) h(z|D = 1) \, dz
\]
\[
- \int \omega_T \log(\tilde{\sigma}_{R,i,t}) f^1(\log(\tilde{\sigma}_{R,i,t})|z) h(z|D = 1) \, dz
\]
Robustness Test: Lagged Tax Rates

<table>
<thead>
<tr>
<th>Sales</th>
<th>Income</th>
<th>Corporate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>Lag</td>
<td>Base</td>
</tr>
<tr>
<td>Bottom Tax Rate</td>
<td>1.495** (0.00400)</td>
<td>0.184** (0.0595)</td>
</tr>
<tr>
<td>Top Tax Rate</td>
<td>0.484** (0.0678)</td>
<td>0.517** (0.0147)</td>
</tr>
<tr>
<td>Economic Controls</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>State FE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>2400</td>
<td>2300</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>.989</td>
<td>.969</td>
</tr>
</tbody>
</table>

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$

Base: $\log(\sigma^2_{R_i,t}) = \beta_0 + \beta_1 \log(\tau_{i,t}) + \beta_2 \log(x_t) ...$

Lag: $\log(\sigma^2_{R_i,t}) = \beta_0 + \beta_1 \log(\tau_{i,t-2}) + \beta_2 \log(x_t) ...$

$\beta_1 = 2 + 2\psi$, implies for corporate rate $\psi = -0.34$.

10% increase in $\tau_c$ implies 3.4% decrease in corporate base and 6.6% increase revenue.
**Omitted Variable Bias Test**

### Robustness Test: Number Of Brackets Omitted.

<table>
<thead>
<tr>
<th>Income</th>
<th>Base</th>
<th>OV</th>
<th>Corporate</th>
<th>Base</th>
<th>OV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottom Tax Rate</td>
<td>0.184**</td>
<td>0.187**</td>
<td>1.322**</td>
<td>1.340**</td>
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</tr>
<tr>
<td></td>
<td>(0.0595)</td>
<td>(0.0829)</td>
<td>(0.0366)</td>
<td>(0.0345)</td>
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</tr>
<tr>
<td>Top Tax Rate</td>
<td>0.484**</td>
<td>0.461**</td>
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</tr>
<tr>
<td></td>
<td>(0.0678)</td>
<td>(0.0744)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Brackets</td>
<td>0.0146</td>
<td>.0939**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0151)</td>
<td>(0.0272)</td>
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</tr>
<tr>
<td>State FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>2400</td>
<td>2400</td>
<td>2400</td>
<td>2400</td>
<td></td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>.915</td>
<td>.915</td>
<td>.967</td>
<td>.967</td>
<td></td>
</tr>
</tbody>
</table>

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$

Base: $\log(\sigma^2_{R_{i,t}}) = \beta_0 + \beta_1 \log(\tau_{i,t}) + \beta_2 \log(x_t) + \beta_3 \log(\text{brackets}_t)$

Omitted Variable (OV): $\log(\sigma^2_{R_{i,t}}) = \beta_0 + \beta_1 \log(\tau_{i,t}) + \beta_2 \log(x_t)$

$\beta_1 = 2 + 2\psi$ implies for corporate rate $\psi = -0.34$.  
10% increase in $\tau_c$ implies 3.4% decrease in corporate base and 6.6% increase revenue.
Structural Break in Early 2000s

Quant Likelihood Ratio:

1. Perform Chow Test for structural break on inner 70%.
2. Break identified by the largest F-statistic.
3. Compare F-statistic to critical value for QLR.

- Benefit agnostic about where structural break is.
- Sometimes referred to as sup Wald test.
<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>IPW</th>
<th>HP Filter</th>
<th>Quartic</th>
<th>Quartic AR1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Income</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tax Policy</td>
<td>68.48 %</td>
<td>65.43 %</td>
<td>81.47 %</td>
<td>94.22 %</td>
<td>102.93 %</td>
</tr>
<tr>
<td></td>
<td>[53.27 , 75.54]</td>
<td>[40.22 , 76.23]</td>
<td>[63.10 , 91.03]</td>
<td>[65.13 , 106.40]</td>
<td>[81.98 , 126.11]</td>
</tr>
<tr>
<td>Business Cycle</td>
<td>30.69 %</td>
<td>33.85 %</td>
<td>17.76 %</td>
<td>4.86 %</td>
<td>-3.77 %</td>
</tr>
<tr>
<td></td>
<td>[18.64 , 39.36]</td>
<td>[20.80 , 45.18]</td>
<td>[-9.09 , 24.93]</td>
<td>[-53.01 , 11.27]</td>
<td>[-31.32 , 5.18]</td>
</tr>
<tr>
<td>Tax Base</td>
<td>0.83 %</td>
<td>0.72 %</td>
<td>0.77 %</td>
<td>0.92 %</td>
<td>0.84 %</td>
</tr>
<tr>
<td></td>
<td>[0.72 , 0.88]</td>
<td>[0.66 , 0.85]</td>
<td>[0.66 , 0.85]</td>
<td>[0.85 , 0.97]</td>
<td>[0.76 , 0.89]</td>
</tr>
<tr>
<td><strong>Sales</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tax Policy</td>
<td>51.56 %</td>
<td>51.38 %</td>
<td>50.72 %</td>
<td>84.91 %</td>
<td>87.22 %</td>
</tr>
<tr>
<td></td>
<td>[-17.54 , 63.32]</td>
<td>[-59.92 , 65.51]</td>
<td>[33.56 , 61.28]</td>
<td>[64.29 , 105.77]</td>
<td>[53.22 , 97.64]</td>
</tr>
<tr>
<td>Business Cycle</td>
<td>47.80 %</td>
<td>48.01 %</td>
<td>48.55 %</td>
<td>14.35 %</td>
<td>12.06 %</td>
</tr>
<tr>
<td></td>
<td>[12.34 , 62.71]</td>
<td>[4.88 , 60.55]</td>
<td>[34.20 , 60.27]</td>
<td>[-16.34 , 18.42]</td>
<td>[-33.89 , 24.71]</td>
</tr>
<tr>
<td>Tax Base</td>
<td>0.64 %</td>
<td>0.61 %</td>
<td>0.73 %</td>
<td>0.74 %</td>
<td>0.72 %</td>
</tr>
<tr>
<td></td>
<td>[0.45 , 0.91]</td>
<td>[-0.10 , 0.83]</td>
<td>[0.63 , 0.82]</td>
<td>[0.51 , 0.80]</td>
<td>[0.64 , 0.88]</td>
</tr>
<tr>
<td><strong>Corporate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tax Policy</td>
<td>87.22 %</td>
<td>82.92 %</td>
<td>72.56 %</td>
<td>92.13 %</td>
<td>96.61 %</td>
</tr>
<tr>
<td></td>
<td>[75.91 , 91.04]</td>
<td>[68.35 , 85.66]</td>
<td>[60.83 , 78.21]</td>
<td>[72.41 , 96.54]</td>
<td>[75.24 , 103.43]</td>
</tr>
<tr>
<td>Business Cycle</td>
<td>11.94 %</td>
<td>16.34 %</td>
<td>26.62 %</td>
<td>7.02 %</td>
<td>2.54 %</td>
</tr>
<tr>
<td>Tax Base</td>
<td>0.84 %</td>
<td>0.74 %</td>
<td>0.82 %</td>
<td>0.85 %</td>
<td>0.85 %</td>
</tr>
<tr>
<td></td>
<td>[0.72 , 0.89]</td>
<td>[0.67 , 0.80]</td>
<td>[0.71 , 0.87]</td>
<td>[0.79 , 0.91]</td>
<td>[0.76 , 0.91]</td>
</tr>
</tbody>
</table>

Bootstrapped 95 percentile confidence interval (3000 replications) clustered by state.
Example Higher Moment Decomposition

Cobb Douglas utility where total consumption distributed uniformly. The density function is $\frac{1}{2\sigma\sqrt{3}}$ for $c \in [-\sqrt{3}\sigma, \sqrt{3}\sigma]$ and zero everywhere else.

$$E[U(c, \beta)] = E[\log c + \alpha \log \beta + (1 - \alpha) \log (1 - \beta)]$$

$$= E[\log[c]] + \alpha \log \beta + (1 - \alpha) \log (1 - \beta)$$

$$= \int_{-\sqrt{3}\sigma}^{\sqrt{3}\sigma} \log c \frac{1}{2\sigma\sqrt{3}} dc + \alpha \log \beta + (1 - \alpha) \log (1 - \beta)$$

$$M(\mu, \sigma^2, \beta) = \frac{(\sigma\sqrt{3} + \mu)(\log(\mu + \sigma\sqrt{3}) - 1) + (\sigma\sqrt{3} - \mu)(\log(\mu - \sigma\sqrt{3}) - 1)}{2\sigma\sqrt{3}} + \alpha \log \beta + (1 - \alpha) \log (1 - \beta)$$
Example Higher Moment Decomposition

Cobb Douglas utility where total consumption distributed uniformly.
The density function is $\frac{1}{2\sigma\sqrt{3}}$ for $c \in [-\sqrt{3}\sigma, \sqrt{3}\sigma]$ and zero everywhere else.

$$E[U(c, \beta)] = E[\log c + \alpha \log \beta + (1 - \alpha) \log (1 - \beta)]$$

$$= E[\log [c]] + \alpha \log \beta + (1 - \alpha) \log (1 - \beta)$$

$$= \int_{-\sqrt{3}\sigma}^{\sqrt{3}\sigma} \log c \frac{1}{2\sigma\sqrt{3}} dc + \alpha \log \beta + (1 - \alpha) \log (1 - \beta)$$

$$M(\mu, \sigma^2, \beta) = \frac{(\sigma \sqrt{3} + \mu)(\log(\mu + \sigma \sqrt{3}) - 1) + (\sigma \sqrt{3} - \mu)(\log(\mu - \sigma \sqrt{3}) - 1)}{2\sigma \sqrt{3}}$$

$$+ \alpha \log \beta + (1 - \alpha) \log (1 - \beta)$$
Causal Interpretation.

Reasons estimates might not be able to be interpreted causally.

1. Plausibility assumption 1.
2. Holland (1986) critique, the “treatment” is not a choice.

Other typical barriers not applicable.

1. Selection on unobservable characteristics.
3. General equilibrium effects.
Causal Interpretation.

Reasons estimates might not be able to be interpreted causally.

1. Plausibility assumption 1.
2. Holland (1986) critique, the “treatment” is not a choice.

Other typical barriers not applicable.

1. Selection on unobservable characteristics.
3. General equilibrium effects.
Sales Tax Rate Changes

Data collected from Book of States and the World Tax Data Base.
Corporate Tax Rate Changes

- Number of Changes
  - Corporate Tax Rate Decreases
  - Corporate Tax Rate Increases

Data collected from Book of States and the World Tax Data Base.
Top Income Tax Rate Changes

Data collected from Book of States and the World Tax Database.
Aggregate Tax Revenue Detrended: Cubic with AR1

Aggregate Tax Revenue Deviations From Trend

Average per capita aggregate tax revenue in 2000s: $1,376
Using flexible polynomial to estimate time trend allows for heterogeneity across states.

Robust to: Kernel estimation, HP filter, cubic and quartic time trend.

Also, semi-parametric power series using Akaike information criterion (AIC).

Additionally: AR1 process filters out serial correlation.

The estimates are robust to the selection of the time trend model.

9 states overweight the sales tax and 19 the income tax. Based on estimates of $\varepsilon_{B,\tau_{s}}, \varepsilon_{B,\tau_{w}}, \varepsilon_{\sigma,\tau_{s}}, \varepsilon_{\sigma,\tau_{w}}$, for each state.

Hawaii balanced, not shown.
Estimates of elasticity of base and volatility with respect to tax rate for each state for the sufficient condition. AK and NH do not have an income or sales tax (AK local sales 7 %)
States without sales tax; DE, MT (3% local), OR (5 % local). States without income tax; FL, NV, SD, TN, TX, WA, WY.
Variance and Correlation of Variables

\[ \sigma \]

\[ \sigma_{\pi} \]

\[ \sigma_{c} \]

\[ \sigma_{wL} \]

\[ \pi \]

\[ c \]

\[ w \]

\[ L \]

\[ \alpha \]

\[ \cos(\alpha) = \text{Correlation}(c, wL) \]

1. \( C = wL + \pi \) in vectors.
2. As \( \sigma_{\pi} \) \( \uparrow \) length \( \pi \) vector \( \uparrow \) \( \rightarrow \) \( \rho_{c,wL} \) \( \downarrow \).
3. As \( \rho_{\pi,wL} \) \( \downarrow \) \( \pi \) vector rotates counterclockwise \( \rightarrow \) \( \rho_{c,wL} \) \( \downarrow \).
Tax Bases Can Be Thought Of As Assets

1. Government’s tax portfolio is a mix of assets (consumption, income, profits, property, etc)

2. Portfolio analysis modified to account for unique position of governments.
   - Increase holding of income tax causes its mean and variance to change.
   - Increase holding of income tax causes other tax revenue’s mean and variance to change.

3. Need to estimate counterfactual revenue streams from different tax portfolios.
   - Weighting method uses all tax revenue data to estimate state-specific minimum-variance frontiers.
California Min.-Variance Frontier and Actual Portfolios

Graph showing the relationship between Variance Tax Revenue (in $ Quadrillions) and Mean Tax Revenue (in $ Billions). The graph displays a curve representing the minimum variance frontier, with actual portfolios marked as points on the curve.
Simplex Example

<table>
<thead>
<tr>
<th>Point</th>
<th>Sales</th>
<th>Income</th>
<th>Corp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>B</td>
<td>0%</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>C</td>
<td>0%</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td>D</td>
<td>33%</td>
<td>33%</td>
<td>33%</td>
</tr>
<tr>
<td>E</td>
<td>0%</td>
<td>50%</td>
<td>50%</td>
</tr>
</tbody>
</table>

Line zz and yy shift between sales and income.
Line xx shift between corporate and income.
Aggregate State Tax portfolios Over Time

Simplex: Top node 100 percent corporate tax revenue (.5,.866), left node 100 percent sales tax (0,0), right node 100 percent income tax (1,0).

Data: State tax revenue from the US Census.
State Tax Portfolios 1955 vs 2005

Simplex: Top node 100 percent corporate tax revenue (.5,.866), left node 100 percent sales tax (0,0), right node 100 percent income tax (1,0). Alaska and New Hampshire not shown.

Data: State tax revenue from the US Census.

Index
Idaho and Nevada Minimum-Variance Frontiers

![Graph showing the minimum-variance frontiers for Idaho and Nevada. The x-axis represents variance in tax revenue ($ Trillions), and the y-axis represents mean tax revenue ($ Billions). Two lines are plotted: one for Idaho and another for Nevada. The line for Idaho is curved, while the line for Nevada is straight.]
Thank you.
Order of Importance

1. The total loss from a tax change can be grouped into; deadweight loss, volatility, and income effects.

2. The loss from a tax change can be approximated by a Taylor series approximation (Harberger, 1964; Diamond and McFadden, 1974).

3. Deadweight loss is of second-order importance because the first term in the Taylor series approximation representing deadweight loss is in the second order approximation.
   - To a linear approximation there is no cost from a tax rate change due to deadweight loss.

4. The order of importance is a comparative statistic about the rate of change in costs from a tax rate change.
Deadweight Loss Difference in Utility.

\[ \beta \beta^{*} \quad \text{d} \beta \quad = \quad \frac{\partial \beta}{\partial \tau} \text{d} \tau \]

Linear approximation is zero \( \Rightarrow \) deadweight loss is of \textit{second-order importance}.
Cost of Volatility in Utility Differences.

-(M(σ^2) + G(σ_g^2))

Linear approximation not zero ⇒ volatility is of *first-order importance.*
Order of Importance

1. Order of importance is about local changes.

2. Therefore in magnitudes (global changes) second-order costs can be larger than first-order costs.

3. Calibrated model demonstrates the cost from volatility is larger than the cost of deadweight loss.
   - Calibrated model estimates full costs. (Advantage)
   - Calibrated model assumes a utility function. (Disadvantage)

4. The cost of volatility is $600 billion per year.
Thank you.
Deadweight loss and Volatility Cost Estimation

1. Log utility function used to calibrate and estimate costs.

2. Calibration done with simulated GMM

3. Welfare calculated in two ways; traditional (Musgrave, 1957; Feldstein, 2008) and new (Seegert 2012b)
   - Traditional: Utility with lump sum taxes minus utility with distortionary taxes.
   - New: Utility with tax rates set by government considering both deadweight loss and volatility minus utility with tax rates set by a government considering only volatility.

   - Traditional: “What is the cost of deadweight loss.”
   - New: “What is the cost of ignoring deadweight loss.”
Calibrated Targets and Moments.

<table>
<thead>
<tr>
<th>Moment</th>
<th>Symbol</th>
<th>Target</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share private consumption</td>
<td>$\beta$</td>
<td>0.467</td>
<td>0.4775</td>
</tr>
<tr>
<td>Labor supply</td>
<td>$L$</td>
<td>0.5000</td>
<td>0.500</td>
</tr>
<tr>
<td>Share public consumption</td>
<td>$g/(c+g)$</td>
<td>0.11</td>
<td>0.1013</td>
</tr>
<tr>
<td>Utility normalization</td>
<td>$\alpha_1 + \alpha_2 + \alpha_3 + \alpha_4$</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Wage income</td>
<td>$wL$</td>
<td>$15,214$</td>
<td>$15,490$</td>
</tr>
<tr>
<td>Profit income</td>
<td>$\pi$</td>
<td>$8,860$</td>
<td>$8,700$</td>
</tr>
<tr>
<td>$c_v(wL)$</td>
<td>$\sigma_{wL}/\bar{w}\bar{L}$</td>
<td>0.0340</td>
<td>0.0341</td>
</tr>
<tr>
<td>$c_v(\pi)$</td>
<td>$\sigma_\pi/\bar{\pi}$</td>
<td>0.083</td>
<td>0.0826</td>
</tr>
<tr>
<td>$\rho_{wL,\pi}$</td>
<td>$\sigma^2_{\pi,wL}/(\sigma_\pi\sigma_{wL})$</td>
<td>0.2265</td>
<td>0.2266</td>
</tr>
</tbody>
</table>

Calibration estimates parameters with simulated GMM.

Nine parameters estimated with nine (nonlinear) moments.
## Calibrated Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Meaning</th>
<th>Value</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha_1$</td>
<td>Share $\beta c$</td>
<td>0.2945</td>
<td>Mikesell (2012)</td>
</tr>
<tr>
<td>$\alpha_2$</td>
<td>Share $(1 - \beta)c$</td>
<td>0.2992</td>
<td>Mikesell (2012)</td>
</tr>
<tr>
<td>$\alpha_3$</td>
<td>Share $g$</td>
<td>0.0421</td>
<td>Gov. expend. (BEA)</td>
</tr>
<tr>
<td>$\alpha_4$</td>
<td>Share leisure</td>
<td>0.3642</td>
<td>Frisch elasticity</td>
</tr>
<tr>
<td>Production</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Share labor</td>
<td>0.6406</td>
<td>$wL$ and $\pi$ (BEA)</td>
</tr>
<tr>
<td>$\mu$</td>
<td>Production tech.</td>
<td>$37,692$</td>
<td>$wL$ and $\pi$ (BEA)</td>
</tr>
<tr>
<td>$\sigma_v$</td>
<td>Persistent shock</td>
<td>$1,148.8$</td>
<td>$\sigma^2_{wL}, \sigma^2_{\pi}$ (BEA)</td>
</tr>
<tr>
<td>$\sigma^2_{\epsilon}$</td>
<td>Temporary shock</td>
<td>$2,539.8$</td>
<td>$\sigma^2_{wL}, \sigma^2_{\pi}$ (BEA)</td>
</tr>
<tr>
<td>$\omega$</td>
<td>Wage smoothing</td>
<td>0.0226</td>
<td>$\rho_{wL,\pi}$ (BEA)</td>
</tr>
</tbody>
</table>

Calibration estimates parameters with simulated GMM.

Nine parameters estimated with nine (nonlinear) moments.
### Deadweight loss and Volatility Cost Estimation

<table>
<thead>
<tr>
<th>Gov. Consideration</th>
<th>Uncertainty</th>
<th>Utility</th>
<th>Percent $U_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$U_1$ Volatility and dwl</td>
<td>Yes</td>
<td>5.600153</td>
<td>100%</td>
</tr>
<tr>
<td>$U_2$ Deadweight loss</td>
<td>No</td>
<td>5.650754</td>
<td>100.9%</td>
</tr>
<tr>
<td>$U_3$ Lump-sum taxes</td>
<td>No</td>
<td>5.700688</td>
<td>100.8%</td>
</tr>
<tr>
<td>$U_4$ Deadweight loss</td>
<td>Yes</td>
<td>5.550783</td>
<td>99.1%</td>
</tr>
<tr>
<td>$U_5$ Volatility</td>
<td>Yes</td>
<td>5.590296</td>
<td>99.8%</td>
</tr>
<tr>
<td>$U_6$ Lump-sum</td>
<td>Yes</td>
<td>5.580723</td>
<td>99.7%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost Comparison</th>
<th>% Consumption</th>
<th>Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volatility</td>
<td>$U_2 - U_1$</td>
<td>8.897%</td>
</tr>
<tr>
<td>Dwl</td>
<td>$U_3 - U_2$</td>
<td>8.773%</td>
</tr>
<tr>
<td>New</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volatility</td>
<td>$U_1 - U_4$</td>
<td>8.671%</td>
</tr>
<tr>
<td>Dwl</td>
<td>$U_1 - U_5$</td>
<td>1.674%</td>
</tr>
<tr>
<td>Additional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Efficient vs Lump</td>
<td>$U_1 - U_6$</td>
<td>3.327%</td>
</tr>
</tbody>
</table>

U.S. population 311,591,917 US Census Bureau, July 2011.
Cost calculations with simulated average consumption $21,739.55.
Thank you.