Tax Revenue Volatility

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Abstract

Revenue volatility affects the welfare of U.S. states, which typically do not smooth their expenditures over the cycle but instead spend revenues as received. Between 2000 and 2014, U.S. state tax revenue volatility increased to 10.8% of revenues, up from 2.9% in the previous three decades. This increase was due to a combination of a rise in the volatility of state GDP and governments relying on different revenue sources, such as income and sales taxes. A Oaxaca-Blinder decomposition indicates that states relying on different tax portfolios explain 59% of the increase in tax revenue volatility and that increased state GDP volatility and all other changes account for 22% and 19%, respectively. This evidence implies that the changes states made to their tax portfolios are responsible for much of the recent increase in state government revenue instability and the welfare consequences that follow from it.

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1 Introduction

The volatility of state tax revenues dramatically increased after 2000. Specifically, it increased to 10.8% of revenues after 2000 from a base of 2.9% in the previous three decades, when volatility is measured as the squared residuals from state-specific time trends. Volatility similarly increased by 7.5 and 8.2 percentage points, when it is measured as year-over-year changes (Cornia and Nelson, 2010) and a four-year rolling variance (Poterba, 1994). This increase in volatility is also widespread: 49 states have experienced a persistent increase in the variability of their tax revenues since 2000.[1] Increased volatility can be decomposed into changes in the revenue sources governments rely on (their tax portfolio), greater volatility in state GDP, and other factors in the tax base. This paper quantifies the importance of each of these in explaining the increase in tax revenue volatility in the 2000s.

Tax revenue volatility affects welfare because states are subject to balanced-budget requirements. These requirements cause states to spend revenues as received, rather than smoothing over the business cycle, as is more typical at the federal level. As a result, unexpected budget shortfalls can immediately impact public good provisions. For example, California cut a billion dollars from core services, including K-12 education, in mid-2012, due to lower-than-predicted revenues.[2] Similarly, former New Jersey Governor Jon Corzine blamed the lack of "predictable, reliable, recurring streams of revenue" for the New Jersey government shut down in 2006. In Governor Corzine's words, the shutdown "means the loss of a paycheck to tens of thousands of construction workers, casino workers, and public employees. It means hardship to small-business owners who will lose income because they can't sell lottery tickets. Make no mistake, people are being hurt and more will be hurt in

[1] Michigan is the only state that did not experience an increase in volatility. Michigan suffered a rise in tax revenue volatility in the 1970s, due to increased economic volatility. To deal with this, Michigan actively changed its tax structure to increase stability—particularly in its business taxes.

[2] States also experienced large positive swings; for example, Nevada experienced a 21.7% increase from 2003 to 2004, and, in 2005, tax revenues exceeded expectations in 24 of the 26 states that report predictions (National Association of State Budget Officers, 2008).

the days ahead."[3]

States rely on several revenue sources to fund the provision of public goods, and each is driven by unique dynamics. Of outsized importance are personal income taxes, sales taxes, and the corporate income tax, and two factors determine the tax revenues from these sources: tax rates and the size of the tax base. The size of the tax base depends on legal rules set by the state and economic conditions, which in turn depend on individual behavior and tax rates. For example, the sales tax base includes the sales of only those goods and services that the state has determined to be taxable. A state can choose to exclude certain items from the tax base, such as food or legal services, and individuals can shift consumption from taxed to untaxed goods and services. Tax revenue volatility therefore depends on three factors: (1) a state's tax portfolio (the revenue sources it relies on); (2) the volatility of economic conditions; and (3) all other potential changes to the tax base. Throughout the paper, I abstract from changes in volatility due to changes in the variance of tax rates. While these changes could affect volatility, in practice, these changes do not seem to explain the increase in volatility based on several descriptive statistics in the data.

Consistent with this decomposition, Figure 1 highlights the fact that tax revenue shocks are strongly correlated with state GDP shocks. Figure 1 also demonstrates that tax revenue volatility increased after 2000, consistent with the findings of Boyd and Dadayan (2014) and Povich (2014), and the mapping between state GDP and tax revenue shocks changed after 2000. Specifically, state GDP shocks and tax revenue shocks occur at the same time and roughly the same magnitude before 2000. After 2000, state GDP and tax revenue shocks still occur at the same time, but the magnitude of tax revenue shocks became disproportionately larger. This evidence suggests that increased volatility of economic factors cannot fully explain the increase in tax revenue volatility observed after 2000 and other factors must also be important. Appropriate policy responses to the increased volatility in the 2000s depend

[3] "N.J. Budget Crisis Shuts Down Casinos and Parks," Richard G. Jones and Laura Mansnerus, July 5, 2006 *The New York Times*.

on the underlying contributors and their relative importance to tax revenue volatility.

I use a Oaxaca-Blinder and a DiNardo-Fortin-Lemieux decomposition to quantify the three contributors to tax revenue volatility: (1) tax portfolios, (2) economic volatility, and (3) all other observed and unobserved tax base factors.[4] These decomposition methods overcome the empirical challenge of measuring tax base changes by modeling tax bases as the mapping from tax rates and economic factors to tax revenues. Changes in the parameter estimates of the model therefore measure the changes in the tax base. This is a substantial benefit, because measuring the tax base is otherwise impossible, due to it being a combination of laws and individual behavior. For example, it is not sufficient to account for all tax law changes (such as changes in the exclusion of ice cream sandwiches in the sales tax base in Milwaukee county), because we would also need to account for behavioral changes (such as changes in the consumption of ice cream sandwiches in Milwaukee county and surrounding counties). The decomposition methods therefore overcome an otherwise intractable problem of trying to quantifying the three contributors to tax revenue volatility.

I find that states changed their tax portfolios in a way that changed the relative reliance of their revenue sources in a way that exposed their tax revenues to more risk and that this change explains a large share of the increase in tax revenue volatility. Using an Oaxaca-Blinder decomposition, I find that changes in their tax portfolio accounts for 59%, changes in GDP volatility account for 22%, and all other tax base differences account for 19% of the increase in tax revenue volatility. Using a DiNardo-Fortin-Lemieux decomposition, I find that changes in their tax portfolio accounts for 67%, changes in GDP volatility account for 13%, and all other differences account for 20% of the increase in tax revenue volatility. Said differently, tax revenues would have been 59% to 67% less volatile in the 2000s had states kept their tax portfolios from before 2000. This evidence implies that changes in

[4]For identification, the decomposition relies on the conditional mean of the error being zero (Rosenbaum and Rubin, 1983, 1984; Heckman, Ichimura and Todd, 1997; Heckman, Ichimura, Smith and Todd, 1998). I perform a battery of tests that suggest that this assumption is plausible in this setting. Fortin, Lemieux and Firpo (2011) provide an extensive overview of decomposition methods.

tax portfolios are responsible for much of the recent increase in state government revenue instability and the welfare consequences that follow from it.

Several additional tests bolster the conclusion that tax revenues became more volatile due to changes in tax portfolios. One concern is that states change their tax portfolio in response to volatility. To test this, I replace concurrent tax portfolios with lagged values. The estimates are very similar, alleviating some of this concern. Estimates are also very similar with region-by-year fixed effects (and state- and year-fixed effects). These specifications control for region shocks and state and year specific differences that otherwise might confound the estimates. The estimates are robust to different measures of volatility, tax portfolios, and economic factors.[5] The estimates are also similar when using different break years and excluding years around the Great Recession.

This work relates to the growing literatures on fiscal stabilization, fiscal federalism, and their interaction. In particular, by studying the volatility of government revenue, this work complements literatures that study how government policies smooth individuals' consumption. For example, automatic stabilizers built into tax and transfer programs have been shown to cushion disposable income by up to 30% in the European Union and up to 20% in the United States (Dolls, Fuest and Peichl, 2012). Despite this stabilization at the federal level, state spending is pro-cyclical in a way that is hard to rationalize, especially infrastructure and equipment spending (Follette, Kusko and Lutz, 2008; Clemens and Miran, 2012; Clemens, 2012). One of the reasons states may have pro-cyclical spending is the real cost associated with smoothing their revenues (Knight and Levinson, 1999).[6] The total stabilization of government tax and transfer programs depends increasingly on state policies, because their budgets, as a percent of total government spending, have continually increased since

[5]For example, the results are not sensitive to measuring volatility as residuals from time trends, year-over-year changes, or a four-year rolling variance or measuring tax portfolios as the statutory tax rates or the average marginal tax rates calculated by NBER or measuring economic factors as state GDP and personal income or using state coincident indexes calculated by the Federal Reserve Bank of Philadelphia.

[6]The analysis in this paper also complements an extensive literature on state fiscal institutions see, e.g., Knight and Levinson (2000).

the 1950s (Baicker, Clemens and Singhal, 2012).[7] I complement these findings by investigating how the reliance of different tax revenue sources affect tax revenue volatility and thus a state's ability to provide fiscal stabilization.

The results of this paper suggest that changing tax portfolios could reverse the increase in tax revenue volatility. In particular, the decomposition points to increased *income tax rates* as the primary driver of increased volatility. A natural question to ask is "Why did states increase their reliance on income taxes?" The answer, in part, is that there were several legal challenges to state tax systems that reduced reliance on the property tax in favor of the income tax. For example, the property tax revolts of the 1970s led states to decrease their reliance on property taxes (for example, Proposition 13 in California in 1978). In addition, a series of school finance court cases (for example, *Robinson v. Cahill* and *Serrano v. Priest*) resulted in state supreme courts ruling that current school funding models that relied mostly on local property taxes were unconstitutional at the state level. As a result, 38 states increased their reliance on the income tax between 1970 and 2000. States therefore may be able to stabilize their tax revenues by shifting back toward property taxes. States could also expand tax bases by including, for example, groceries and services in their sales tax base or by reducing the progressivity of their income tax (Seegert, 2015). Of course, the gains from stability would need to be contrasted with the costs from other objectives of optimal taxation, including efficiency and equity.

The paper proceeds as follows. Section 2 documents the empirical puzzle that tax revenue volatility increased in the 2000s. Section 3 describes the decomposition methods used to quantify the contribution of different factors on the increase in tax revenue volatility. Section 4 reports the main findings. Section 5 discusses the identification and robustness of the decomposition estimates. Section 6 discusses the results in different contexts, and section 7 concludes.

[7]For an analysis of E.U. stabilization with the introduction of an E.U. wide tax and transfer program, see Bargain, Dolls, Fuest, Neumann, Peichl, Pestel and Siegloch (2013).

2 Data and Descriptive Statistics

2.1 Data Collection

I collected data on tax revenues, tax rates, and economic factors for all states between 1970 and 2014. Data on tax revenues come from the Book of States and the U.S. Census of Governments.[8] Tax rate data were collected from and cross-checked with the Book of States, the World Tax Database, the Advisory Commission on Intergovernmental Relations biannual report "Significant Features in Fiscal Federalism," and the Tax Foundation.

2.2 Data Definitions

2.2.1 Aggregate Tax Revenue

For the following analysis, I define aggregate tax revenues as the sum of income, sales, and corporate tax revenues. In 2000, these three revenue sources accounted for roughly 75% of state government revenues. I focus on these three revenue sources to be able to compare across states.[9] For example, there are large differences in the importance of oil and mineral revenues across states, and differences in property assessments preclude comparison of property tax rates; thus I exclude them from the main analysis.[10]

[8] There are approximately a dozen inconsistencies between the Book of States and the U.S. Census of Governments. In these cases, I use data from the Book of States, though the analysis is robust to using the data from the U.S. Census of Governments. State tax revenue data for 2001 and 2003 are absent from these sources. Data in those years are interpolated, and the analysis is robust to excluding these years.

[9] I abstract from intergovernmental grants. See Knight (2002) and Lutz (2010) on recent evidence of intergovernmental grant crowd out.

[10] The results in Table 2, which show that tax rates are an important factor in tax revenue volatility, are made stronger when I account for property and mineral tax revenues in total tax revenue. Property tax revenues are relatively stable and countercyclical (Lutz, Molloy and Shan, 2011). One reason the revenues may be countercyclical is that property tax revenues lag housing price appreciation (Lutz, 2008). After the property tax revolts in the 1970s, state and local governments have relied less on property taxes. Therefore, adding property taxes provides evidence of another way tax rate changes increased tax revenue volatility.

2.2.2 Measuring Volatility

To capture the shocks that state governments face, I define volatility as the squared residual from a state-specific time trend. This measure estimates the amount of volatility or the unpredictableness in a given variable. I measure the shocks relative to a time trend using a state-specific fifth-order polynomial based on the Akaike Information Criterion (AIC). The measure is robust to using different time trends, including any polynomial between a third and ninth order.[11] The results throughout the paper are robust to measuring volatility as year-over-year changes or as a four-year rolling variance. Estimates using the other measures are reported in Table 4. In practice, all of these measures are similar (as Table 1 and Figure A.1 will show).

I also report estimates measuring volatility as the square root of the squared residual divided by tax revenues in Table A.9. The advantage of this measure is that tax revenue volatility is measured as a percentage of revenues. The disadvantage of this measure is that it can be difficult to interpret changes in ratios. From the government's perspective it is not clear whether levels or percentages are more meaningful, and both provide information. For example, if the state faces more volatility because they must raise more revenues to cover additional expenditures this is an important cost to weigh against increasing expenditures. The results do not differ using a volatility measure scaled by revenues or not, and, therefore, I leave for future work discussions of whether volatility should be measured in percentages or levels.

The residual measure is conservative because it nets out state-specific time trends that the other measures conflate with volatility. It also closely aligns with shocks to state tax revenues and converges to the population variance when averaged together in the decomposition. For these reasons, the baseline results are reported using the residual measure. Appendix A.1further discusses these measures of volatility.

[11] Table A.5 reports estimates using a third-order through ninth-order polynomial. The measure is also robust to using an HP filter or trends that only use lagged data.

2.2.3 Economic Factors

To capture economic factors in each state, I collect data on state GDP, personal income, and population from the Bureau of Economic Analysis and the U.S. Census Bureau.[12] As an additional test, I also use state coincident indexes, calculated by the Federal Reserve Bank of Philadelphia, as a different measure of economic conditions. Coincident indexes combine state-level indicators into a single statistic to summarize economic conditions. The index includes nonfarm payroll employment, average hours worked in manufacturing by production workers, the unemployment rate, and wage and salary disbursements deflated by the consumer price index (U.S. city average).[13]

2.2.4 Before and After Sample Years

The panel includes 45 years of data. The analysis splits the data into before-and-after periods to compare changes in volatility. The baseline break year is 2000, such that the groups are 1970–1999 and 2000–2014. The break year is determined by a structural break test, and results are robust to a three-year window around the structural break (see Table A.6).

2.3 Documenting an Empirical Puzzle: An Increase in Tax Revenue Volatility

Panel A of Figure 1 shows residuals from a time trend as a percent of the level of aggregate state tax revenue, depicted as a solid blue line. Before 2000, tax revenue shocks are relatively small, less than 5%, but after 2000, there are shocks greater than 10%—some positive and

[12] All of the estimations are done in real aggregate terms controlling for population. The results are robust to using real per capita variables without controlling for population. The first strategy is preferred because it is more general than the second, which unnecessarily constrains the coefficient on population in the estimates. The estimates are also robust to different measures of volatility including the residual scaled by tax revenues (see Appendix B).

[13] The coincident indexes are created using a dynamic single-factor model. For more information, see Crone and Clayton-Matthews (2005) and https://www.philadelphiafed.org/research-and-data/regional-economy/indexes/coincident/.

some negative. Aggregate state GDP shocks are depicted as a green dashed line for comparison. Before 2000, the magnitudes of shocks to tax revenues and state GDP are similar, but after 2000, the shocks to tax revenue become disproportionately large.

Table 1 shows that tax revenue volatility increased dramatically in the 2000s. This table provides estimates of the change in volatility from 1970-1999 to 2000-2014 for each state using three measures of volatility: year-over-year changes, the four-year rolling standard deviation, and a residual measure of volatility. In the period 1970-1999, the average volatility in tax revenues was 2.93% and increased to 10.8% in the period 2000-2014, using the residual measure.[14]

Table 1 documents that 49 states experienced increases in volatility and 16 states, including California and New Jersey, experienced substantial increases of more than 10 percentage points in all three measures of volatility.[15] Michigan is the only state that experienced a decrease in volatility, potentially because it experienced extreme economic volatility in the 1970s and adjusted its tax rates afterward to provide stability. This evidence suggests that the observed increase in tax revenue volatility affected most states and that there is considerable variation across states in the magnitude of the increase of volatility.

3 Decomposing Tax Revenue Volatility

This section derives an empirical strategy to decompose tax revenue volatility into three pieces: 1) the tax portfolio (which revenue sources a state relies on) 2) economic uncertainty, and 3) all other factors. Section 3.2 derives an econometric model for tax revenue volatility. Section 3.4 combines this econometric model and a Oaxaca-Blinder decomposition to produce

[14] Table A.1 reports that the year-over-year changes and the absolute value of a four-year rolling standard deviation volatility increased from 5.34% and 7.09% before 2000 to 12.77% and 15.34% after 2000, respectively.

[15] The increases in volatility are statistically significant at the 10% level for 45 states using the four-year rolling standard deviation or residual measure and for 40 states using the year-over-year measure. These are denoted with superscripts in Table 1.

the main empirical specification. Finally, a visual example in section 3.5 builds intuition for this decomposition.

3.1 Tax Revenue Portfolio Choice

Governments rely on different revenue sources with different weights—similar to assets in an investor's portfolio. A tax base j, such as personal income or sales, in state s and year t is a function of a vector of economic conditions $\boldsymbol{x}$ and a vector of tax rates $\boldsymbol{\tau}$, given by $B_{j,s,t}(\boldsymbol{\tau}, \boldsymbol{x})$.[16] For example, the income tax base increases as the economy expands and people's income increases. The tax base also depends on tax rates. For example, the income tax base decreases with the income tax rate, because people work less, and likely increases with the corporate tax rate, to the extent that people shift corporate revenues into personal income. Total tax revenues are a weighted combination of tax bases, where the weights are the tax rates,

$$R_{s,t} = \sum_{j} \tau_{j,s,t} B_{j,s,t}(\boldsymbol{\tau}, \boldsymbol{x}). \tag{1}$$

The revenues a state receives depends on the whole portfolio of revenue sources a state relies on. Some states rely heavily on one or two tax revenue sources, such as Washington, which does not tax personal income, and Oregon, which does not tax sales. Other states choose a more diversified portfolio of revenue sources. These choices have a direct effect, through the tax rate given by the first term on the right hand side, and an indirect effect, through the tax base. For example, the corporate tax rate could have spillovers on income tax revenues. These spillovers are captured by the vector of tax rates in the tax base function. Each state's tax portfolio exposes them to different levels of risk.

Using the accounting identity in equation (1), I can write the aggregate tax revenue volatility as a combination of tax rates, volatility of tax bases, and the corresponding co-volatilities, denoted by $\sigma^2(B_{j,s,t})$ and $\sigma(B_{j,s,t}, B_{i,s,t})$, where i represents a tax base not j. The

[16] The economic conditions a state faces are taken as exogenous.

co-volatility between tax bases j and tax base i is defined as $\sigma(B_{j,s,t}, B_{i,s,t}) = \varepsilon_{j,s,t} * \varepsilon_{i,s,t}$; when $j = i$, the co-volatility is the volatility of tax base j. This gives the equation,

$$\sigma^2(R_{s,t}) = \sum_j \tau_{j,s,t}^2 \sigma^2(B_{j,s,t}) + \sum_j \sum_{i \neq j} \tau_j \tau_i \sigma(B_{j,s,t}, B_{i,s,t}). \tag{2}$$

This equation demonstrates that the reliance of different tax revenue sources is determined by the level of tax rates. This analysis therefore tests whether or not changes in the reliance of different tax revenue sources exposed state tax revenues to more risk from state GDP.

I decompose the aggregate tax revenue volatility into its components, e.g., income tax revenue volatility, and then decompose each of those components. The tax revenue volatility of a given revenue source j equals the tax rate squared times the volatility of the tax base:

$$\sigma^2(R_{j,s,t}) = \tau_{j,s,t}^2 \sigma^2(B_{j,s,t}(\boldsymbol{\tau}, \boldsymbol{x})). \tag{3}$$

Equation (3) implicitly assumes the tax rate is constant. Ultimately this assumption is consistent with the data, the Oaxaca-Blinder decomposition that I employ, and allows me to test the main hypothesis of the paper that the reliance of different revenue sources led to the increase in tax revenue volatility. In the data tax rates do not change often and the frequency at which tax rates have changed has not changed before or after 2000, making this approximation seem reasonable. The Oaxaca-Blinder decomposition compares the average characteristics before 2000 to the average characteristics after 2000, which is indifferent to the variance of these characteristics. Of course, other assumptions could be made to test different hypotheses. This is explored more in Appendix B.2.[17]

[17] Appendix B.2 tests the alternative hypothesis that changes in the variance of tax rates contributed to the increase in tax revenue volatility. Table A.11 reports the estimates from this decomposition. The evidence suggests that the change in the variance of tax rates does not explain the increase in tax revenue volatility. Based on this evidence, the analysis focuses on how changes in the reliance of different revenue sources, caused by changes in the level of the tax rate, affected tax revenue volatility.

3.2 Deriving Tax Revenue Volatility

This section derives an econometric model for tax revenue volatility in the same way that Oaxaca (1973) and Blinder (1973) derive a model for wages. First, take the log of the accounting identity for the volatility of tax revenue from source j given in equation (3):

$$log(\sigma^2(R_{j,s,t})) = 2 * log(\tau_{j,s,t}) + log(\sigma^2(B_{j,s,t}(\boldsymbol{\tau}, \boldsymbol{x}))). \tag{4}$$

The volatility of the tax base, $\sigma^2(B_{j,s,t}(\boldsymbol{\tau}, \boldsymbol{x}))$, is a function of tax rates and the volatility of economic conditions modeled as

$$\begin{aligned} log(\sigma^2(B_{j,s,t}(\boldsymbol{\tau}, \boldsymbol{x}))) = \alpha + (\gamma_j - 2)log(\tau_{j,s,t}) + \sum_{i \neq j} \gamma_i log(\tau_{i,s,t}) \\ + \sum_k \delta_k log(\sigma^2(x_{k,s,t})) + \lambda_s + \lambda_t + \varepsilon_{j,s,t} \end{aligned} \tag{5}$$

where $log(\tau_{j,s,t})$ is the log of the tax rate on tax base j, $log(\boldsymbol{\tau}_{i,s,t})$ is the log of tax rate on revenue source $i \neq j$, $log(\sigma^2(x_{k,s,t}))$ is the log of the volatility of economic condition k, and λ_s and λ_t are state and year fixed effects.[18] The coefficient γ_j captures behavioral responses that may cause a revenue source, such as income taxes, to become more or less volatile as the income tax rate increases. For example, if higher income taxes lead people to be less likely to start side business projects—with more volatile income—then higher income tax rates may cause the income tax base to become less volatile and $\gamma_j < 0$. If instead higher income tax rates create an income effect that encourages people to start side projects—with more volatile income—then higher income tax rates may cause the income tax base to become more volatile and $\gamma_j > 0$.

[18] One potential concern with these derivations is the assumed linearity of the approximations in equation (5) (Barsky et al., 2002). The concern is that this functional form is misspecified and could lead to bias. While Kline (2010) shows that this is not a concern in practice, I also estimate the decomposition following the methods developed by DiNardo et al. (1996), which do not rely on the linearity structure. The nonparametric results, reported in Table 4, are similar to the baseline estimates, which suggests that the linearity of the approximations are not driving the results.

The coefficients on the other tax rates, γ_i, capture spillover effects of different tax rates on tax revenue volatility. For example, the volatility of income tax revenues may depend on the corporate tax rate. In particular, if people are less likely to incorporate their business when the corporate tax rate is high, then the income tax base may become more volatile because it includes more business income, which might be more volatile. In this case, the sign of γ_i would be positive on the corporate tax rate. The coefficients on the log of volatility of the economic conditions, δ_k, captures how economic volatility leads to tax revenue volatility. For example, the coefficient on the volatility of state GDP for the sales tax base is likely to be positive, because the sales tax base is some function of state GDP.

Combining equations (4) and (5) produces an econometric model from the derivations of tax revenue volatility in this section:

$$log(\sigma^2(R_{j,s,t})) = \alpha + \sum_j \gamma_j log(\tau_{j,s,t}) + \sum_k \delta_k log(\sigma^2(x_{k,s,t})) + \lambda_s + \lambda_t + \varepsilon_{j,s,t}. \qquad (6)$$

Equation (6) states that tax revenue volatility is determined by a state's tax portfolio (how much a state relies on each revenue source), economic uncertainty, and the mapping of those variables to tax revenue—captured by the coefficients α, γ_j, and δ_k. All other tax base factors are captured by the mapping of tax rates and economic uncertainty to tax revenue volatility. For example, consider a state that includes grocery sales in its sales tax base. This policy affects the tax base and changes the effect of tax rates and economic uncertainty on tax revenue volatility through changes in α, γ_j, and δ_k. Similarly, if individuals choose to buy more untaxed goods and services, this will lower the sales tax base. These responses will also change the effect of tax rates and economic uncertainty on tax revenue volatility. The model captures this change as changes in α, γ_j, and δ_k.

3.3 Estimating Tax Revenue Volatility

The estimation uses panel data from 50 states and the years 1970 to 2014 to estimate equation (6). This model is run separately for each tax revenue source j. An observation, therefore, is a state-year, denoted s and t. The baseline specification uses within-state variation across time by including state- and year-fixed effects. I use state- and year-fixed effects to control for potential confounding factors. For example, state-fixed effects control for idiosyncratic unobserved omitted variables contributing to tax revenue volatility and, if they are correlated with tax rates or economic volatility, would otherwise bias those estimates and the decomposition. In practice, omitted variables do not seem to matter, because estimates are not sensitive to the inclusion or exclusion of state- and year-fixed effects and region by year fixed effects.[19] Section 5.5 tests for other potential confounding factors and finds the estimates are similar across a wide array of specifications.

The baseline specifications include the volatility of state GDP, personal income volatility, and population to measure economic uncertainty. Section 5.3 demonstrates the estimates are not sensitive to other measures of economic uncertainty, including the volatility of the coincident index calculated by the Federal Reserve Bank of Philadelphia. Tax rates are measured as the statutory top and bottom income tax rates, sales tax rates, and corporate tax rates, and all of these tax rates are included for all revenue sources. Section 6.3 demonstrates the estimates are not sensitive to using different definitions of tax rates. Tax revenue volatility is measured as the squared residual from a state-specific time trend in tax revenues (see section 2.2.2). The estimates are robust to other measures, including using a four-year rolling variance, year-over-year differences, and the squared residual scaled by tax revenues (see section 5.2).

I extend the discussion of the econometric model in several ways. Appendix B.3 reports

[19] Table A.8 finds similar coefficients from the regression of income tax revenue volatility on the baseline tax and economic factors with and without the state and year fixed effects (discussed more in Appendix B.3).

and discusses the coefficients from equation (6) to highlight how differences in tax instruments have contributed to increases in tax revenue volatility. Appendix A.2 and Appendix A.3 complement that discussion by providing descriptive statistics on the variation in tax rates and economic uncertainty before and after 2000. Section 6.3 reports specifications that include several measures of income tax progressivity to investigates the sensitivity of the estimates to different measures of tax structures. Appendix B.3 discusses the role of state and year variation in estimating equation (6).

3.4 Decomposing Each Tax Base

The Oaxaca-Blinder decomposition provides a mechanism for separating the contributions of different factors. The innovation here is that although tax bases are complex functions their contribution can be accurately quantified using the model derived in Section 3.2 and a Oaxaca-Blinder decomposition. Define the average level of tax revenue volatility in period p, where period p is either the years before or after 2000, as,

$$\overline{log(\sigma^2(R_{j,p}))} = \hat{\alpha}_p + \sum_j \hat{\gamma}_j \overline{log(\tau_{j,p})} + \sum_k \hat{\delta}_k \overline{log(\sigma^2(x_{k,p}))} + \overline{\lambda}_{s,p} + \overline{\lambda}_{t,p} + \varepsilon_{j,p}, \tag{7}$$

where $\overline{log(\sigma_j^2)}_p$, $\overline{log(\tau_{j,p})}$, and $\overline{log(\sigma^2(x_{k,p}))}$ are the averages of tax revenue volatility, log tax rates, and log of the volatility of economic conditions in period p, respectively. The average OLS error term $\varepsilon_{j,p}$ is zero by construction and therefore disappears.

The change in average tax revenue volatility before and after 2000, denoted by $p = 0$ and

$p = 1$, can be written as,

$$\begin{aligned}\overline{log(\sigma^2(R_{j,1}))} - \overline{log(\sigma^2(R_{j,0}))} =& \hat{\alpha}_1 + \sum_j \hat{\gamma}_{j,1}\overline{log(\tau_{j,1})} + \sum_k \hat{\delta}_{k,1}\overline{log(\sigma^2(x_{k,1}))} \\ & - \hat{\alpha}_0 - \sum_j \hat{\gamma}_{j,0}\overline{log(\tau_{j,0})} - \sum_k \hat{\delta}_{k,0}\overline{log(\sigma^2(x_{k,0}))} \\ & + \overline{\lambda}_{s,1} + \overline{\lambda}_{t,1} + \varepsilon_{j,1} - \overline{\lambda}_{s,0} - \overline{\lambda}_{t,0} - \varepsilon_{j,0}.\end{aligned} \tag{8}$$

By adding and subtracting $\sum_j \hat{\gamma}_{j,0}\overline{log(\tau_{j,0})} + \sum_k \hat{\delta}_{k,0}\overline{log(\sigma^2(x_{k,0}))}$ and grouping terms, the contribution of changes in tax portfolios (given by changes in tax rates), economic uncertainty, and changes in the tax base can be quantified by the first, second, and third and fourth lines, respectively,

$$\begin{aligned}\overline{log(\sigma^2(R_{j,1}))} - \overline{log(\sigma^2(R_{j,0}))} =& \sum_j \left(\overline{log(\tau_{j,1})} - \overline{log(\tau_{j,0})}\right)\hat{\gamma}_{j,0} \\ & \sum_k \left(\overline{log(\sigma^2(x_{k,1}))} - \overline{log(\sigma^2(x_{k,0}))}\right)\hat{\delta}_{j,0} \\ & + \sum_k \left(\hat{\delta}_{k,1} - \hat{\delta}_{k,0}\right)\overline{log(\sigma^2(x_{k,1}))} + \sum_j \left(\hat{\gamma}_{j,1} - \hat{\gamma}_{j,0}\right)\overline{log(\tau_{j,1})} \\ & \hat{\alpha}_1 - \hat{\alpha}_0 + \overline{\lambda}_{s,1} + \overline{\lambda}_{t,1} - \overline{\lambda}_{s,0} - \overline{\lambda}_{t,0} \\ & + \bar{\varepsilon}_{j,1} - \bar{\varepsilon}_{j,0}.\end{aligned} \tag{9}$$

The first line in equation (9) captures the effect of changing tax portfolios on tax revenue volatility, holding constant the OLS coefficients. This is equivalent to the counterfactual change in tax revenue volatility, due to changes in tax portfolios, if the mapping between tax rates and tax revenue volatility had stayed constant.

The second line in equation (9) captures the effect of changing economic uncertainty on tax revenue volatility, holding constant the OLS coefficients. This effect is equivalent to the counterfactual change in tax revenue volatility, due to economic uncertainty changes, if the mapping between economic uncertainty and tax revenue volatility had stayed constant.

The third and fourth lines in equation (9) accounts for all other tax base changes including active tax base changes, due to governments changing which goods are taxable, and passive tax base changes, due to changes in individual buying behavior.[20] For example, if capital gains become a larger proportion of the income tax base after 2000, then the same income tax rate would map to more income tax revenue volatility, which would be captured by $\hat{\gamma}_{j,1} > \hat{\gamma}_{j,0}$. Similarly, the sales tax base has shrunk as a percentage of overall GDP, due to an increase in spending on services and online sales. If the proportion of state GDP in the sales tax base after 2000 is now on average more volatile then state GDP, then $\hat{\delta}_{k,1} > \hat{\delta}_{k,0}$, because the same level of state GDP volatility will lead to a proportionally larger increase in sales tax revenue volatility after 2000.

Finally, the last line captures any biases from the estimation. With the identifying assumption that the conditional mean of the error is zero, $E[\varepsilon|x,\tau] = 0$, this last line is zero. In this case, the previous lines capture the changes due to changes in the tax portfolio, the volatility of economic conditions, and all other changes. Section 5 provides a broader discussion of the identification assumption, the plausibility of this assumption in this setting, and evidence from a battery of tests. The estimates are also shown to be robust when using a nonparametric reweighting approach proposed by DiNardo, Fortin and Lemieux (1996).[21]

[20] The decomposition method employed captures tax base changes through changes in the mapping of tax rates and economic uncertainty into tax revenue volatility. This decomposition overcomes the empirical challenge of collecting data on all legislative tax base changes, which is not practical. To demonstrate the impracticality of collecting data on all legislative tax base changes, consider one such change in Wisconsin. In 2009, Wisconsin changed the law such that ice cream sandwiches sold in grocers' frozen food sections are no longer subject to the local food and beverage tax on marshmallows in Milwaukee County (http://www.revenue.wi.gov/faqs/pcs/expo.html. Tax 11.51 Guidelines "Marshmallows unless they contain flour.").

[21] Fortin, Lemieux and Firpo (2011) have shown that these reweighted decomposition methods provide consistent estimates with no functional form assumptions and with no parametric assumptions on the joint distribution of the independent variables, the dependent variable, or the group variable.

3.5 Visual Decomposition Example

Before reporting the full decomposition results in the following section, this section provides a visual decomposition using the raw mapping between tax revenue volatility and economic uncertainty.

Figure 2 graphs the relationship between tax revenue volatility and economic uncertainty.[22] There is a definite positive relationship between tax revenue volatility (vertical axis) and economic uncertainty (horizontal axis). There is a noticeable shift in this relationship after 2000, which can be seen from all of the points before 2000 (denoted by hollow red circles) being below the points after 2000 (denoted by solid blue circles). A solid red best fit line gives the relationship before 2000, and the dashed blue best fit line gives the relationship after 2000. Both lines seem to be good models of the relationship between tax revenue volatility and state-level GDP, because the scatter points are close to their best fit lines. The change in the relationship between tax revenue volatility and economic uncertainty incorporates all factors contributing to tax revenue volatility other than economic volatility, including tax rates.

Figure 2 depicts three points. Point A depicts state GDP volatility and tax revenue volatility before 2000 (1.8%, 2.9%). Point B depicts state GDP volatility after 2000 and the tax revenue volatility after 2000 if tax rates and all other factors had remained the same (2.5%, 3.5%). Point C depicts state GDP volatility and tax revenue volatility after 2000 (2.5%, 10.8%). Figure 2 decomposes the change in tax revenue volatility from A to C into the part due to an increase in state GDP volatility (A to B) and the part due to an increase in all other factors, including tax rates (B to C). The following thought experiment quantifies the contribution of the increase in economic volatility and the change in the relationship in explaining the increase in tax revenue volatility. First, if state GDP volatility increased from 1.8% to 2.5% and the relationship between tax revenue volatility and state-level GDP

[22] Specifically, Figure 2 is a binned scatter plot of state-level tax revenue volatility and state-level GDP volatility from 1970 to 2014.

volatility did not change, tax revenue volatility would have increased from 2.9% to 3.5%. The remaining increase in observed tax revenue volatility, from 3.5% to 10.8%, is attributed to the change in the relationship between tax revenue volatility and state GDP volatility, given by the differences in the best fit lines.

This simple decomposition suggests that changes in state-level GDP volatility explain 8% of the increase in tax revenue volatility and tax rates and other changes explain 92%. Section 4 reports estimates that use a Oaxaca-Blinder decomposition, which controls for other factors, to more precisely separate tax rates, economic uncertainty, and all other factors.

4 Determinants of Tax Revenue Volatility

This section reports the decomposition estimates. Section 4.1 decomposes aggregate tax revenue volatility into its components, income, sales, corporate tax revenue volatility and the corresponding co-volatilities. Section 4.2 decomposes each of those components into the contribution of tax rates, economic uncertainty and tax base changes. Section 4.3 combines the estimates from the previous two sections to calculate the aggregate contribution of tax rates, economic uncertainty and tax base changes. Finally, section 4.4 provides an example of the decomposition using California and Colorado.

4.1 Aggregate Decomposition of Tax Revenue Volatility

Panel A of Table 2 reports the contribution of income, sales, corporate tax revenue volatility and their corresponding co-volatilities to aggregate tax revenue volatility. By construction, the sum of the contributions over columns (1)–(6) is one. Column (1) reports that 35% of the aggregate increase in tax revenue volatility is due to the increase in income tax revenue volatility. In comparison, sales and corporate tax revenue volatility increased aggregate volatility by 13% and 3%, respectively, reported in columns (2) and (3). Columns (4)–(6)

report the contribution of co-volatility. The sum of the co-volatility contributions is 49%, which suggests that a substantial portion of the increase in aggregate tax revenue volatility is due to changes in co-volatility as well as individual tax revenue source volatilities.

4.2 The Contribution of Tax Portfolios, Economic Uncertainty, and Tax Base Changes To Each Revenue Source

Panel B of Table 2 presents the results of the decomposition in equation (9). By construction, the sum of the contributions of the changes to tax portfolios, tax bases, and economic uncertainty in rows 1–3 in Panel B is one for each column. Following equation (9), the percent change reported in each entry is calculated by multiplying the change in average values of income, sales, and corporate tax rates and volalility of state GDP by the OLS coefficients estimated before 2000. (These components are reported in Table A.7.)

Consider the decomposition of income tax revenue volatility reported in column (1). The first row in column (1) reports that tax portfolios account for 67% of the increase in income tax revenue volatility, and rows 2 and 3 report that tax base and economic uncertainty changes account for 10% and 23%, respectively. These estimates represent the change in tax revenue volatility predicted by the change in the reliance on different revenue sources, economic uncertainty, and tax base changes, holding all else constant. Specifically, these estimates suggest that income tax revenue would have been 67% lower in the 2000s if tax portfolios had been the same as they were before 2000.

The estimates are all reasonably precise. All three of the estimates in column (1) are statistically significantly different from zero and one another at the 1% level. Bootstrapped standard errors are reported in parentheses and clustered at the state level.[23]

Columns (2) through (6) report similar analyses for the volatility of sales and corporate

[23] These estimates represent the estimates for the average state, where each state is given equal weight in the estimation. Alternatively, section Appendix B.5 reports estimates for the average person weighting the estimates by state population.

tax revenues and the corresponding co-volatility (similar to covariances). Tax portfolios explain 58% of the increase in sales tax revenue volatility (column 2) and 15% of corporate tax revenue volatility (column 3). Tax portfolios also explain 71%, 30%, and 68% of the increases in co-volatility of income and corporate tax revenues (column 4), income and sales tax revenues (column 5), and sales and corporate tax revenues (column 6), respectively. The top row across all six columns suggest that the contribution of tax portfolios in explaining tax revenue volatility is substantial.

The tax base explains between 3% and 67% of the increase in tax revenue volatilities and co-volatilities—due to small differences in income and sales tax bases and large differences in corporate tax bases. The tax base contribution is relatively small, 10% and 16%, in explaining the increase in income and sales tax revenue volatility (columns 1 and 2, respectively). In contrast, the tax base contribution is relatively large, 67%, in explaining the increase in corporate tax revenue volatility (column 3). These estimates are consistent with many states making more changes to the corporate tax base through changing apportionment rules and other deductions than by changing personal income or sales tax bases.

Economic uncertainty explains between 16% and 26% of the increase in tax revenue volatilities and co-volatilities. For example, economic uncertainty explains 23%, 26%, and 18% of the volatility of income, sales, and corporate tax revenues, reported in columns (1), (2), and (3), respectively. These estimates suggest that economic turmoil from the 2001 and 2008 recessions increased tax revenue volatility. The contribution of economic uncertainty is relatively similar across revenue sources, especially in contrast to the heterogeneity in contributions for the tax base.

4.3 Aggregate Contribution

Combining the estimates in Panels A and B produces the aggregate contribution of changes in tax portfolios, economic uncertainty, and tax bases. Consider the contribution of tax portfolios, reported in the first row of Panel B. To aggregate its contribution, multiply the value in each column by the aggregate contribution in Panel A and add these weighted contributions across columns. For example, changes in tax portfolios explain 59% of aggregate tax revenue volatility; $0.59 = 0.67 \times 0.35 + 0.58 \times 0.13 + 0.15 \times 0.03 + 0.72 \times 0.24 + 0.30 \times 0.18 + 0.68 \times 0.07$. Through a similar analysis, I find that differences in economic uncertainty and tax bases explain 22% and 19% of aggregate tax revenue volatility, respectively. These estimates suggest that, to a striking degree, state governments caused the increase in volatility that they experienced in the 2000s by changing the revenue sources they rely on.

4.4 California and Colorado

This section considers how tax revenue volatility has changed in California and Colorado, reported in Table 3. For this example, the decomposition consists of one tax rate and one economic variable. The coefficients are estimated using all 50 states before 2000. Following equation (9), I combine these coefficients with the change in tax rate and economic conditions in California and Colorado to decompose these states' tax revenue volatility. California and Colorado are used for this example because both experienced 10% to 13% increases in tax revenue volatility, reported in Table 1, and tax portfolios and economic uncertainty contributed differently to this increase.

First, consider income tax revenue volatility in California and Colorado, reported in Panel A of Table 3. I use the average marginal income tax rate in a given state-year calculated by NBER for a fixed sample of taxpayers from 1984 to capture the tax portfolio and the log of state GDP volatility for changes in economic uncertainty.[24] Column (1) reports that the coefficient on the average marginal tax rate is 5.454, which suggests that increasing your reliance on income tax revenues will increase your income tax revenue volatility. Columns (2) and (3) report that California increased its average marginal income tax rate by 0.438, while

[24]The average marginal tax rates from the NBER can be found at http://users.nber.org/~taxsim/allyup/.

Colorado decreased its tax rate by 0.077. Columns (4) and (5) report the overall change in income tax revenue volatility, which is used to scale the change due to economic volatility. Columns (6) and (7) report the contribution of each factor in explaining the change in tax revenue volatility by combining the coefficient in column (1), the change in tax rates in columns (2) and (3), and scaling this by the change in tax revenue volatility reported in columns (4) and (5). For example, column (6) suggests that income tax revenue volatility in California would have been 72% lower after 2000 if California had not changed the revenue sources it relied on. In contrast, column (7) suggests that income tax revenue volatility in Colorado would have been 17% higher if Colorado had not changed its tax portfolio.

The second row of panel A of Table 3 calculates the contribution of economic uncertainty to income tax revenue volatility. Column (1) reports the coefficient is 0.466, which suggests that an increase in economic uncertainty leads to an increase in income tax revenue volatility. Columns (2) and (3) report that California's economic uncertainty increased after 2000, while Colorado's decreased. Columns (4) and (5) report the overall change in income tax revenue volatility. Columns (6) and (7) report that California's income tax revenue volatility would have been 17% lower after 2000 if its economic uncertainty had stayed the same as it had been before 2000. In contrast, Colorado's income tax revenue volatility would have been 27% higher after 2000 if its economic uncertainty had stayed the same as it had been before 2000. Changes in the tax base explain the remaining change in income tax revenue volatility unexplained by changes in tax rates and economic volatility. Formally, the contribution of changes in the tax base is given by the change in coefficients estimated before and after 2000, as in equation (9). The changes capture all factors that change the mapping from tax rates and economic volatility into tax revenue volatility. Panels B and C of Table 3 repeat this example for the volatility of sales and corporate tax revenues.

5 Identification and Sensitivity

5.1 Identification

The identification of decomposition methods follows the treatment effect literature (Rosenbaum and Rubin, 1983, 1984; Heckman, Ichimura and Todd, 1997; Heckman, Ichimura, Smith and Todd, 1998) and has been extensively discussed by Fortin, Lemieux and Firpo (2011). The baseline estimates rely on the ignorability assumption (sometimes referred to as unconfoundedness). This assumption states that, conditional on observable characteristics, the distribution of unobserved explanatory factors of tax revenue volatility is the same before and after 2000. The ignorability assumption rules out selection into groups based on unobservables and is plausible in this context because we observe all states before and after 2000. Identification also requires overlapping support across observable characteristics before and after 2000. The overlapping support requirement ensures that no value of an observable characteristic perfectly predicts whether an observation comes from before or after 2000, which holds in this setting. The ignorability and overlapping support assumptions identify the counterfactual distribution used to decompose the effects of changes in tax rates and economic uncertainty on tax revenue volatility.[25] The zero conditional mean assumption is required to separately identify the contributions of differences in tax rates and economic uncertainty.[26]

The panel data allow for controls that bolster the plausibility of the zero conditional mean assumption in this setting. For example, the panel data allow for state- and year-fixed

[25] Barsky et al. (2002) suggests that the implicit linearity assumption in equation (5) may be inappropriate in some contexts and propose a more flexible approach as in DiNardo, Fortin and Lemieux (1996). Following this suggestion, I test for the sensitivity of the model using the nonparametric reweighting approach in DiNardo et al. (1996). This specification does not rely on any of the structures presented in section 3.2 and produces similar results. Kline (2010) demonstrates that the standard decomposition is doubly robust, can be thought of as a reweighting estimator, and therefore is robust to departures from the linearity assumption (Fortin et al., 2011).

[26] General equilibrium effects could limit a causal interpretation if the counterfactuals of interest are out of sample. In this setting, however, the counterfactuals of interest are within sample, because they are tax policies from previous decades.

effects that add to the plausibility of the identifying assumption and are included in the baseline estimates.

The following sections investigate the plausibility of the identifying assumption and sensitivity of the estimates. Table 4 reports the estimates are similar with additional controls for omitted variables and simultaneity of tax rate decisions and tax revenue volatility (see section 5.5 below). If the estimates had not been similar, this would have indicated a potential threat to identification. Table 4 also reports the estimates are not sensitive to different measures of volatility (discussed in section 5.2), different measures of economic uncertainty (discussed in section 5.3), different sample years (discussed in section 5.4), and a nonparametric decomposition method (discussed in section 5.6). Additional tests are reported in Tables A.4, A.5, and A.6 and discussed in Appendix B.

5.2 Sensitivity to How Volatility is Measured

Columns (1) and (2) of Table 4 report the decomposition estimates using a four-year rolling variance and year-over-year differences as measures of volatility. The estimates using either of these alternative measures resemble the baseline numbers in Table 2. For example, Panel A reports that changes in tax portfolios explain 78% and 79% of the increase in income tax revenue volatility using the rolling variance or year-over-year measures, respectively, which are both similar to the 67% estimate in Table 2. Similarly, Panel A reports that differences in economic uncertainty explain 23% and 22% of the increase in income tax revenue volatility using the rolling variance or year-over-year measures, respectively, which are both similar to the 23% estimate in Table 2. These estimates suggest that the residual measure of volatility used in the baseline specification produces a conservative estimate of the importance of tax portfolios in explaining tax revenue volatility.[27] Appendix A.1 provides a larger discussion

[27] The baseline estimates use the residual measure without scaling by tax revenues to avoid complications in interpretation. Table A.9 reports that the estimates are similar when the volatility measure is the residual scaled by tax revenues. See Appendix B.

of these different volatility measures.

Columns (4) and (5) of Table 4 report the decomposition estimates calculating volatility using a fourth order and sixth order polynomial to estimate the state-specific time trends rather than a fifth order polynomial, which is used in the estimates in Table 2. The estimates are not sensitive to using different orders of a polynomial. For example, Panel A reports that changes in tax portfolios explain 68% and 66% of the increase in income tax revenue volatility using a fourth order and sixth order polynomial, respectively, which are both similar to the 67% estimate in column (1) of Table 2. Additional specifications using third- to ninth-order polynomials are reported in Appendix Tables A.5 and similarly find the estimates are not sensitive to how the time trend is estimated.

5.3 Sensitivity to How Economic Uncertainty is Measured

Column (3) of Table 4 reports an estimate using a different measure of economic uncertainty. This specification tests whether there are confounding or omitted factors in how economic uncertainty is measured. This specification uses the volatility of coincident indexes, calculated by the Federal Reserve Bank of Philadelphia, to measure economic uncertainty in a given state-year observation. The coincident indexes combine state-level indicators into a single statistic to summarize economic conditions and include nonfarm payroll employment, average hours worked in manufacturing by production workers, the unemployment rate, and wage and salary disbursements deflated by the consumer price index (U.S. city average). The estimates are not sensitive to using the coincident index instead of state GDP. For example, Column (3) of Panel A of Table 4 reports that changes in tax portfolios and economic uncertainty account for 71% and 20%, respectively, of the increase in income tax revenue volatility, which are similar to the 67% and 23% baseline estimates reported in column (1) of Table 2. The similarity of the estimates suggests that the estimates are not driven by the specific choice of variables capturing economic uncertainty.

5.4 Sensitivity to Sample Years

Columns (6) and (7) of Table 4 report that estimates using different break years for the before and after comparison. Columns (6) and (7) use 1999 and 2001 as the break year rather than 2000 in the baseline estimates in Table 2; Table A.6 reports estimates using all years between 1997 and 2003 as the break year with similar results. The estimates are not sensitive to using different break years. For example, Panel A reports that changes in tax portfolios explain 66% of the increase in income tax revenue volatility using both 1999 and 2001 as the break years, which is similar to the 67% estimate in column (1) of Table 2. Table A.4 reports estimates excluding the years of the financial crisis (2008 and 2009, 2008 through 2010, and 2007 through 2010) and finds estimates similar to the baseline estimates reported in Table 2. The similarity of estimates suggests the estimates are not sensitive to the set of years used for the comparison, which is consistent with the large changes in tax rates from 1970 to 2014 depicted in Figure A.2.

5.5 Potential Confounding Factors

Columns (8) and (9) of Table 4 report estimates investigating potential conflating and omitted factors. For example, a threat to validity would occur if there were unobserved region shocks. To test this, I include region-year fixed effects into the specification reported in column (8), where the regions are determined by clustering states based on similarities in the fraction of employment and GDP in each industry. These specifications control for potential policy spillovers from neighboring states.[28] The estimates with region-year fixed effects resemble the baseline estimates. For example, Column (8) of Panel A reports that changes in tax portfolios explain 66% of the increase in income tax revenue volatility, similar to the 67% in the baseline estimates reported in column (1) of Table 2.

[28]For example, Wilson (2009) finds that state R&D credits draw R&D from other states, and Moretti and Wilson (2017) find that state tax policy can attract high-earners. Both of these spillovers may impact tax revenue and its volatility.

Column (9) replaces the tax rates with the two-year lagged tax rate values. This specification tests for potential contamination due to state governments changing their tax rates in response to contemporary tax revenue. This may be less of a concern because the volatility of tax revenue is defined as the squared deviations from a flexible time trend, or transitory shocks, which makes conditioning policies on them difficult. The estimates in Column (9) resemble the baseline estimates in Table 2. For example, column (9) in Panel A reports that changes in tax portfolios explain 62% of the increase in income tax revenue volatility, similar to the 67% in the baseline estimates reported in column (1) of Table 2.

The similarity in estimates in columns (8) and (9) of Table 4 with the baseline estimates in Table 2 supports the plausibility of the identifying assumption in this context. Specifically, these estimates limit the potential omitted conflating factors. These estimates also alleviate some concern about whether the results are being driven by policy choices in response to shocks in tax revenues, because tax rates two years prior cannot respond to a contemporaneous shock in tax revenues. Additional specifications with different regions and one- and two-year lagged values of tax rates are reported in Table A.4.

5.6 Nonparametric Estimates

To test the sensitivity of the estimates to the parametric assumptions in the baseline specification, I estimate the model using the nonparametric decomposition pioneered by DiNardo, Fortin and Lemieux (1996). These estimates are reported in Column (10) of Table 4 in Panels A, B, and C for the income, sales, and corporate tax, respectively. Relative to the baseline estimates reported in Table 2, the contribution of tax portfolios is slightly larger when I use the nonparametric decomposition. For example, the estimates in column (10) in Table 4 suggest that changes in tax portfolios explain 89%, 83%, and 54% of the increase in income, sales, and corporate tax revenues, respectively, relative to 67%, 58%, and 15% in the baseline estimates.

Combined with the aggregate decomposition in section 4.1, these estimates suggest that tax portfolios differences explain 67% of the increase in tax revenue volatility. Economic uncertainty and tax base changes explain 13% and 20%, respectively.[29] These estimates suggest that the baseline specifications produce conservative estimates of the importance of tax portfolios in explaining tax revenue volatility.

6 Discussion

This section discusses several outstanding questions about tax revenue volatility. Section 6.1 demonstrates one reason that tax revenue volatility is costly is that it leads to volatility in expenditures. Given this cost and the role changes in tax portfolios had in increasing tax revenue volatility, section 6.2 discusses potential reasons why states changed their tax portfolios in this way. Section 6.2.1 discusses the role of capital gains in the observed increase in tax revenue volatility. Finally, section 6.3 demonstrates that the results are not sensitive to different measures of changes in the income tax, including using measures of progressivity.[30] Together the following section provides additional context for the estimates previously discussed.

6.1 Variation in State Expenditures

Volatility in state expenditures in the 2000s is one of the motivations for investigating changes in tax revenue volatility. Panel B of Figure 1 demonstrates how much states can limit the costs of tax revenue volatility by smoothing expenditures relative to revenues. Panel B of Figure 1 shows that state government expenditure shocks, as a percentage of revenues, are

[29] Figure A.3 graphs the actual and counterfactual distribution, using the nonparametric method by DiNardo, Fortin and Lemieux (1996), of log tax revenue volatility.

[30] Appendix B.4 demonstrates how the methods in this paper can be used for other revenue sources using motor fuel tax revenues. Appendix B.5 considers the effects of the average person in the US instead of the average state.

roughly the same magnitude as state tax revenue shocks.[31] This similarity in the magnitudes of shocks suggests that state governments are ineffective in smoothing tax revenue shocks. Balanced budget rules and other political economy frictions may explain the inability of state governments to smooth tax revenue shocks.[32] In addition, other policies, such as rainy day funds, have been shown to be ineffective tools and potentially very costly for smoothing government expenditures. For example, Sobel and Holcombe (1996) suggest that to maintain state government expenditures through the 1991 recession, states would have needed rainy day funds of 30% of their general expenditures.[33]

6.2 Variation in Reliance of Income Tax Revenue

Changes in tax portfolios contributed to increased tax revenue volatility in the 2000s. One of the largest changes was an increased reliance on the income tax. Between 1970 and 2000, income tax revenues increased from 32.6% to 44.0% of revenues from income, sales, and corporate tax revenues. During the same period, sales tax revenues decreased from 56.5% to 45.3%, and corporate tax revenues remained similar.[34] Thirty-eight states increased their reliance on the income tax between 1970 and 2000. For example, Ohio and Pennsylvania went from not taxing income in 1970 to having income tax revenues in 2000 account for 54.5% and 43.6% of their revenues, respectively. California increased its reliance on the income tax from 32.9% in 1970 to 56.8% in 2000.[35] These changes in tax portfolios are explored more in Figure A.2.

[31] Figure 1 shows that state expenditure shocks lag state tax revenue shocks, consistent with the results from a Granger causality test.

[32] Novy-Marx and Rauh (2012) investigate the cost of borrowing for state governments.

[33] Panel B of Figure 1 provides some evidence that the American Recovery and Reinvestment Act of 2009, which provided $831 billion of expenditure support, may have damped state government expenditure shocks after 2009. See Wilson (2012) for other impacts of the American Recovery and Reinvestment Act of 2009.

[34] There is a large and important literature on discretionary fiscal effects that is separate from the broad shifts in tax rates discussed here. See work by Follette, Kusko and Lutz (2008); Hines (2010) and Cashin, Lenney, Lutz and Peterman (2017).

[35] Six states decreased their reliance on the income tax between 1970 and 2000. For example, Alaska collected most of its revenue (86%) from the income tax in 1970 and did not collect income taxes in 2000. Six states did not collect income taxes in 1970 or 2000.

The reasons why states changed their tax portfolios are outside of the scope of this paper, but, as discussed in the introduction, two potential catalysts are a series of court cases about school funding and the property tax revolts in the 1970s and 1980s. The court cases ruled that funding education with local property taxes violated state constitutional requirements for an equal and adequate education. These court cases led states to shift reliance from property taxes (which tend to be local) to income taxes (which are statewide). One prominent example of this shift occurred in New Jersey in response to *Robinson v. Cahill*, 1970. Due to inaction by the New Jersey legislature to find an alternative school-finance mechanism, the New Jersey Supreme Court closed public schools for eight days in 1976. Shortly after that, New Jersey adopted the state income tax. By 2000, income tax revenues accounted for 35% of New Jersey's tax revenues.[36] Similar policy changes occurred in other states, either as direct responses to court cases or indirect responses in attempts to avoid such cases.[37] These shifts also coincided with the property tax revolts in the 1970s and 1980s, which put more pressure on states to find revenue sources to compensate for lost property tax revenue.

6.2.1 Capital Gains

A consequence of relying more on income taxes is that states also relied more on capital gains, which are part of the income tax base. The literature on taxing risky capital income has typically focused on efficiency costs (Gordon and Wilson, 1989). There has been recent interest, however, in the link between capital gains and the volatility of tax revenues (Washington Policy Center, 2015; Comptroller of Maryland, 2016). The estimates in Table

[36]Similar court cases occurred in California (*Serrano v. Priest*, 1971), Connecticut (*Horton v. Meskill*, 1977), Washington (*Seattle School District No. 1 v. State*, 1978), West Virginia (*Pauley v. Kelly*, 1979), Kentucky (*Rose v. Council for Better Education*, 1985), and Montana (*Helena Elementary School District No. 1 v. State*, 1985).

[37]For example, Washington responded to a court case by passing the Basic Education Act. This act caused the state to assume responsibility for fully funding basic education. To fulfill this responsibility, Washington relied solely on increasing sales tax revenues, causing the sales tax rate to increase from 4.5% in 1976 to 6.5% by 1983.

2 confirm that states relying more on income taxes and therefore capital gains contributed to the increase in tax revenue volatility. The tax base factor in Table 2 captures the contribution of increases in the volatility of capital gains, relative to economic conditions, such as GDP and personal income, which seems to have contributed less than changes in tax portfolios.

6.3 Measuring Changes in Income Taxes

The baseline estimates use the statutory top and bottom income tax rates to characterize how states changed their income tax over time. The estimates resemble other measures of changes in income taxes across states. For example, the income tax system can be quantified using the average marginal and average tax rate in a state. Table 5 uses the marginal and average tax rates for the US calculated by the NBER using a fixed sample of taxpayers from 1984.[38] These estimates suggest that changes in tax portfolios explain 78% of the increase in income tax revenue volatility, which is similar to the baseline estimate of 67%. The income tax system can also be quantified by including measures of how progressive the income tax is. Table 6 reports estimates using nine different measures of the progressivity of a state calculated by Peichl and Ochmann (2006) and posted on the NBER website.[39] The estimates when the variable post-tax Gini, as a measure of income tax progressivity, is included, suggest that changes in tax portfolios explain 72% of the increase in income tax revenue volatility, which resembles the baseline estimate of 67%.

[38] The marginal and average tax rates from the NBER can be found at www.users.nber.org/~taxsim/allyup/.

[39] The progressivity for an income tax system can be found at www.users.nber.org/~taxsim/newprog84.html.

7 Conclusion

State governments continue to have fiscal difficulties as a result of an unprecedented increase in tax revenue volatility. Average state tax revenue volatility increased from an average of 2.9% of revenues in 1970-1999 to 10.8% in 2000-2014. This paper determines how changes in tax portfolios and economic uncertainty contributed to this increase in tax revenue volatility. I find that tax revenues would have been 59% to 67% less volatile between 2000 and 2014 if state governments had not changed their tax portfolios.

The large increase in tax revenue volatility in the 2000s and the apparent inability of state governments to smooth their revenues motivates future research on state policies. First, more research is needed to understand why state governments cannot smooth their revenues. The reasons may be policies that can be changed, such as balanced budget rules, or frictions innate to state governments that cannot be changed, such as potential agency and political economy issues. Second, if state governments continue to be unable to smooth their revenues, what is the optimal tax policy?

Additional research should also investigate how tax revenue volatility contributes to economic uncertainty. For example, tax revenue volatility may act as a shock of uncertainty to firms and damp their investment (Bloom, 2009, 2007; Bloom, Bond and Van Reenen, 2007).

The results may also be extended to models of fiscal federalism. If tax revenue volatility enters governments' objective function negatively and the federal government can smooth revenues better than state governments, then there is an added role for fiscal federalism. For example, such a model could help clarify the costs and benefits of recent proposals at the federal level to use block grants.

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Table 1: **Change in Tax Revenue Volatility from 1970–1999 to 2000–2014**

This table reports changes in tax revenue volatility between 1970–1999 and 2000–2014 from the specification

$$Vol_{i,t} = \eta_i + \beta_i \eta_i d(Year > 1999) + \varepsilon_{i,t},$$

where $Vol_{i,t}$ is the measure of volatility given in the column heading reported in percentages for ease of comparison, η_i is an indicator for state i, $d(Year > 1999)$ is an indicator equal to one for years greater than 1999 and zero otherwise, and β_i is the state-specific coefficient on the post-1999 indicator interacted with the state indicator. Column (1) reports volatility as year-over-year changes, calculated as $(x_t - x_{t-1})/x_{t-1}$. Column (2) reports volatility as the rolling standard deviation, using a four-year window, calculated as $\sqrt{var(x)}/(\text{Tax Revenues}_t)$ over this window. Column (3) reports volatility as the residuals from a flexible state-specific time trend, calculated as $\sqrt{\varepsilon^2}/(\text{Tax Revenues}_t)$. Statistical significance at the 10, 5, and 1 percent levels are denoted by *, **, and ***, respectively.

Reported statistic: β_i change in tax revenue volatility from 1970–1999 to 2000–2014.

	Volatility Measure				Volatility Measure		
State	Year-Over-Year	4-Year Rolling	Residual from Trend	State	Year-Over-Year	4-Year Rolling	Residual from Trend
Alabama	6.16*	7.07**	7.90***	Montana	11.93***	14.31***	12.08***
Alaska	3.15	11.83***	2.97	Nebraska	9.17**	9.35***	5.48**
Arizona	14.03***	17.58***	15.00***	Nevada	8.94**	10.19***	9.48***
Arkansas	5.72*	6.95**	6.79**	New Hampshire	11.23***	11.10***	9.15***
California	12.96***	12.09***	11.99***	New Jersey	9.83***	10.30***	9.46***
Colorado	10.73***	10.33***	10.74***	New Mexico	8.12**	9.83***	9.63***
Connecticut	8.52**	10.78***	10.34***	New York	7.88**	7.19**	6.45**
Delaware	6.84*	4.31	5.64*	North Carolina	5.57*	6.33**	7.10***
Florida	8.77**	10.41***	10.72***	North Dakota	18.29***	24.77***	10.06***
Georgia	6.74*	6.43**	8.81***	Ohio	4.31	4.42	5.89**
Hawaii	6.80*	8.97***	7.01***	Oklahoma	7.51**	8.75***	8.55***
Idaho	12.62***	13.06***	11.70***	Oregon	11.68***	8.98***	9.89***
Illinois	8.24**	12.00***	10.27***	Pennsylvania	4.37	4.44	4.96*
Indiana	3.77	4.69*	4.08	Rhode Island	5.90*	4.69*	5.54**
Iowa	5.42	6.53**	5.84**	South Carolina	5.64*	6.34**	7.05***
Kansas	6.84*	7.21**	7.96***	South Dakota	3.67	3.94	3.04
Kentucky	2.79	3.19	3.77	Tennessee	6.74*	6.91**	5.59**
Louisiana	10.41***	14.41***	11.94***	Texas	12.07***	10.37***	8.47***
Maine	3.19	4.1	4.11*	Utah	8.87**	10.85***	11.71***
Maryland	5.1	5.51*	4.38*	Vermont	8.89**	9.33***	8.04***
Massachusetts	9.01**	7.51**	7.38***	Virginia	7.00*	7.58***	8.34***
Michigan	−0.02	−1.83	−0.31	Washington	5.59	5.10*	7.40**
Minnesota	6.89*	6.77**	6.14**	West Virginia	1.94	3.03	2.58
Mississippi	4.55	5.75*	6.54**	Wisconsin	3.44	2.32	4.82*
Missouri	3.75	4.49*	4.72*	Wyoming	19.18***	24.81***	14.95***
				Adj. R-Square	0.55	0.74	0.59
				Observations	2200	2150	2250

Table 2: **Tax Revenue Volatility Decomposition**

This table reports estimates based on Oaxaca-Blinder decomposition. Columns (1) through (3) report the decomposition of income, sales, and corporate tax revenue volatility, respectively, and columns (4) through (6) report the decomposition of the associated co-volatilities. Panel A reports the aggregate decomposition specified in equation (2). Panel B reports the contribution in percentage of differences in reliance of revenue sources, economic uncertainty, and tax bases for each tax base using the specification in equation (9). All specifications include state and year fixed effects. Volatility of revenue and economic variables is calculated as the squared residual, $\varepsilon_{i,t}^2$, from a regression of the variable x and a flexible state-specific time trend. Bootstrapped standard errors (5,000 replications) clustered by state are reported in parentheses below the estimates. Statistical significance at the 10, 5, and 1 percent levels are denoted by *, **, and ***, respectively.

	Volatility			Co-volatility		
	Income (1)	Sales (2)	Corporate (3)	(Inc., Corp.) (4)	(Inc., Sales) (5)	(Sales, Corp.) (6)
Panel A: Aggregate Decomposition						
Percent of Total	0.35	0.13	0.03	0.24	0.18	0.07
Panel B: Detailed Decomposition						
Tax Portfolio	0.671***	0.583***	0.153***	0.718***	0.304***	0.682***
	(0.004)	(0.002)	(0.004)	(0.003)	(0.002)	(0.003)
Tax Base	0.100***	0.157***	0.669***	0.034***	0.519***	0.157***
	(0.004)	(0.002)	(0.005)	(0.003)	(0.002)	(0.003)
Economic Uncertainty	0.229***	0.260***	0.178***	0.248***	0.177***	0.162***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
State Fixed Effects	✓	✓	✓	✓	✓	✓
Year Fixed Effects	✓	✓	✓	✓	✓	✓
Observations	2250	2250	2250	2250	2250	2250

Table 3: **Decomposition Example**

This table provides an example of a Oaxaca (1973) and Blinder (1973) decomposition using a reduced set of factors and two states, California and Colorado. Columns 1 and 2 report estimates of the regression of tax revenue volatility of the income, sales, and corporate tax using one tax and economic factor. The reliance on different revenue sources is measured by the tax rate for the given base. For the income tax, the average marginal tax rate calculated by NBER is used (see the discussion in section 6.3). The economic factor is the log of state GDP volatility. Columns 3–6 report the average factor before and after 2000 in California and Colorado. Columns 7 and 8 report the contribution of each factor for California and Colorado, respectively. Panel A reports these estimates for the income tax. Panel B and C report these estimates for the sales and corporate tax respectively. Standard errors are reported in parentheses below the estimates. Statistical significance at the 10, 5, and 1 percent levels are denoted by *, **, and ***, respectively.

	Coefficients	Difference in Factor Averages		Difference in Volatility		Factor Contributions	
						$\frac{\beta_{before}(\bar{x}_{after} - \bar{x}_{before})}{\bar{Y}_{after} - \bar{Y}_{before}}$	
	β_{before}	$\bar{x}_{after} - \bar{x}_{before}$		$\bar{Y}_{after} - \bar{Y}_{before}$			
	Before 2000	California	Colorado	California	Colorado	California	Colorado
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Income Tax							
Income tax rate	5.454***	0.439	-0.077	3.302	2.488	0.725	-0.169
	(0.069)						
log(state GDP volatility)	0.466***	1.204	-1.454	3.302	2.488	0.170	-0.272
	(0.059)						
Panel B: Sales Tax							
Sales tax rate	0.717***	2.445	-0.128	4.176	0.142	0.420	-0.646
	(0.074)						
log(state GDP volatility)	0.035***	1.204	-1.454	4.176	0.142	0.010	-0.358
	(0.004)	(0.006)					
Panel C: Corporate Tax							
Corporate tax rate	1.054***	-0.416	-0.490	2.543	2.948	-0.172	-0.175
	(0.046)						
log(state GDP volatility)	0.396***	1.204	-1.454	2.543	2.948	0.187	-0.195
	(0.043)						

Table 4: **Additional Specifications**

Panels A, B, and C report the decomposition for income, sales, and corporate tax revenues, respectively. Columns (1) and (2) report estimates using four-year rolling variance and year-over-year differences as measures of volatility. Column (3) uses the volatility of coincident indexes, calculated by the Federal Reserve Bank of Philadelphia, as a different measure of economic uncertainty. Columns (4)–(7) report estimates using different model parameters. For additional model parameter specifications, see Tables A.5 and A.6. Column (8) reports estimates with region by year fixed effects where regions are determined by clustering states based on similarities in the fraction of employment and GDP in each industry. Column (9) reports specifications with tax rates lagged by two years. Column (10) reports the estimates using the nonparametric decomposition pioneered by DiNardo, Fortin and Lemieux (1996), which loosens the parametric assumptions in the baseline estimates. Volatility of revenue and economic variables is calculated as the squared residual from a regression of the variable x and a flexible state-specific time trend. Bootstrapped standard errors (5,000 replications) clustered by state are reported in parentheses below the estimates. Statistical significance at the 10, 5, and 1 percent levels are denoted by *, **, and ***, respectively.

	Rolling	Year-	Coincident	Polynomial		Break Years		Region×	Tax Rate	DFL
	Variance	over-Year	Index	4th	6th	1999	2001	Year FE	t-2	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A: Income Tax Revenue										
Tax Portfolio	0.778***	0.792***	0.712***	0.679***	0.683***	0.662***	0.659***	0.635***	0.616***	0.886***
	(0.002)	(0.003)	(0.013)	(0.004)	(0.004)	(0.004)	(0.003)	(0.013)	(0.003)	(0.004)
Tax Base	−0.004***	−0.012***	0.081***	0.157***	−0.038***	0.101***	0.089***	0.270***	0.063***	−0.128***
	(0.001)	(0.001)	(0.013)	(0.004)	(0.004)	(0.004)	(0.003)	(0.012)	(0.005)	(0.005)
Economic Uncertainty	0.226***	0.220***	0.207***	0.164***	0.355***	0.237***	0.252***	0.095***	0.321***	0.243***
	(0.002)	(0.003)	(0.003)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)
Panel B: Sales Tax Revenue										
Tax Portfolio	0.723***	0.751***	0.577***	0.551***	0.574***	0.591***	0.590***	0.497***	0.545***	0.835***
	(0.002)	(0.004)	(0.009)	(0.003)	(0.002)	(0.002)	(0.002)	(0.008)	(0.003)	(0.005)
Tax Base	−0.001	−0.011***	0.200***	0.225***	0.105***	0.145***	0.133***	0.367***	0.098***	0.005***
	(0.001)	(0.001)	(0.009)	(0.003)	(0.003)	(0.003)	(0.002)	(0.007)	(0.005)	(0.005)
Economic Uncertainty	0.278***	0.260***	0.206***	0.224***	0.322***	0.263***	0.277***	0.135***	0.357***	0.161***
	(0.002)	(0.004)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	(0.001)
Panel C: Corporate Tax Revenue										
Tax Portfolio	0.230***	0.494***	0.170***	0.153***	0.151***	0.181***	0.153***	0.096***	0.349***	0.543***
	(0.002)	(0.004)	(0.015)	(0.005)	(0.004)	(0.004)	(0.005)	(0.015)	(0.002)	(0.004)
Tax Base	0.699***	0.317***	0.662***	0.701***	0.608***	0.642***	0.622***	0.848***	0.318***	0.318***
	(0.002)	(0.004)	(0.016)	(0.005)	(0.005)	(0.005)	(0.005)	(0.015)	(0.004)	(0.004)
Economic Uncertainty	0.071***	0.188***	0.168***	0.146***	0.241***	0.177***	0.226***	0.056***	0.334***	0.139***
	(0.001)	(0.001)	(0.003)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)
State FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Observations	2150	2200	2250	2250	2250	2250	2250	2250	2250	2250

Table 5: **Alternative Income Tax System Measures**

The tax system can be measured in several ways. The baseline estimates characterize the tax system by the top and bottom statutory income tax rates. This table reports estimates that characterize the tax system using the average and average marginal tax rates for each state in each year, which is estimated by NBER. The estimates of the average and average marginal tax rate uses a fixed sample of taxpayers from 1984. The marginal and average tax rates from the NBER can be found at www.users.nber.org/~taxsim/allyup/. Standard errors are reported in parentheses below the estimates. Statistical significance at the 10, 5, and 1 percent levels are denoted by *, **, and ***, respectively.

	Volatility			Co-volatility		
	Income	Sales	Corporate	(Inc., Corp.)	(Inc., Sales)	(Sales, Corp.)
	(1)	(2)	(3)	(4)	(5)	(6)
Tax Portfolio	0.781***	0.486***	0.137***	0.690***	0.606***	0.655***
	(0.004)	(0.002)	(0.004)	(0.001)	(0.001)	(0.001)
Tax Base	0.028***	0.255***	0.700***	0.016***	0.132***	0.044***
	(0.004)	(0.002)	(0.005)	(0.001)	(0.001)	(0.001)
Economic	0.191***	0.259***	0.164***	0.293***	0.262***	0.301***
Uncertainty	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
State Fixed Effects	✓	✓	✓	✓	✓	✓
Year Fixed Effects	✓	✓	✓	✓	✓	✓
Observations	2250	2250	2250	2250	2250	2250

Table 6: **Alternative Measures of Income Tax Progressivity**

This table reports estimates using different measures of income tax progressivity. The baseline estimates characterize the tax system by the top and bottom statutory income tax rates. The estimates in this table add to the baseline estimates measures of progressivity from NBER and Peichl and Ochmann (2006), which can be found at `www.users.nber.org/~taxsim/newprog84.html`. Standard errors are reported in parentheses below the estimates. Statistical significance at the 10, 5, and 1 percent levels are denoted by *, **, and ***, respectively.

	Income Tax Revenue Volatility								
	Post-tax Gini (1)	Average Rate (2)	Reynolds Smolensky (3)	Katwani (4)	Vertical Equity (5)	Reranking (6)	Suits (7)	Musgrave Thin (8)	Atkinson Plotnick (9)
Tax Portfolio	0.722*** (0.007)	0.495*** (0.006)	0.485*** (0.003)	0.621*** (0.004)	0.490*** (0.003)	0.734*** (0.004)	0.628*** (0.003)	0.511*** (0.003)	0.714*** (0.004)
Tax Base	0.062*** (0.007)	0.292*** (0.006)	0.299*** (0.003)	0.168*** (0.004)	0.294*** (0.003)	0.054*** (0.004)	0.161*** (0.003)	0.273*** (0.003)	0.074*** (0.004)
Economic Uncertainty	0.216*** (0.001)	0.213*** (0.001)	0.216*** (0.001)	0.211*** (0.001)	0.216*** (0.001)	0.211*** (0.001)	0.211*** (0.001)	0.216*** (0.001)	0.212*** (0.001)
State Fixed Effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
Year Fixed Effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
Observations	2250	2250	2250	2250	2250	2250	2250	2250	2250

Table 7: **Average Volatility Experienced by Individuals**

This table reports the baseline estimates estimates where the state-year observations have been weighted by population to provide estimates for the average person. Bootstrapped standard errors (5,000 replications) clustered by state are reported in parentheses below the estimates. Statistical significance at the 10, 5, and 1 percent levels are denoted by *, **, and ***, respectively.

	Volatility			Co-volatility		
	Income	Sales	Corporate	(Inc., Corp.)	(Inc., Sales)	(Sales, Corp.)
	(1)	(2)	(3)	(4)	(5)	(6)
Tax Portfolio	0.875***	0.331***	0.265***	0.656***	0.613***	0.563***
	(0.005)	(0.002)	(0.006)	(0.001)	(0.001)	(0.001)
Tax Base	0.033***	0.321***	0.443***	0.006***	0.042***	0.006***
	(0.005)	(0.002)	(0.005)	(0.001)	(0.001)	(0.001)
Economic	0.092***	0.347***	0.293***	0.338***	0.345***	0.432***
Uncertainty	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
State Fixed Effects	✓	✓	✓	✓	✓	✓
Year Fixed Effects	✓	✓	✓	✓	✓	✓
Observations	2250	2250	2250	2250	2250	2250

Figure 1: **State Tax Revenue, GDP, and State Government Expenditure Shocks**

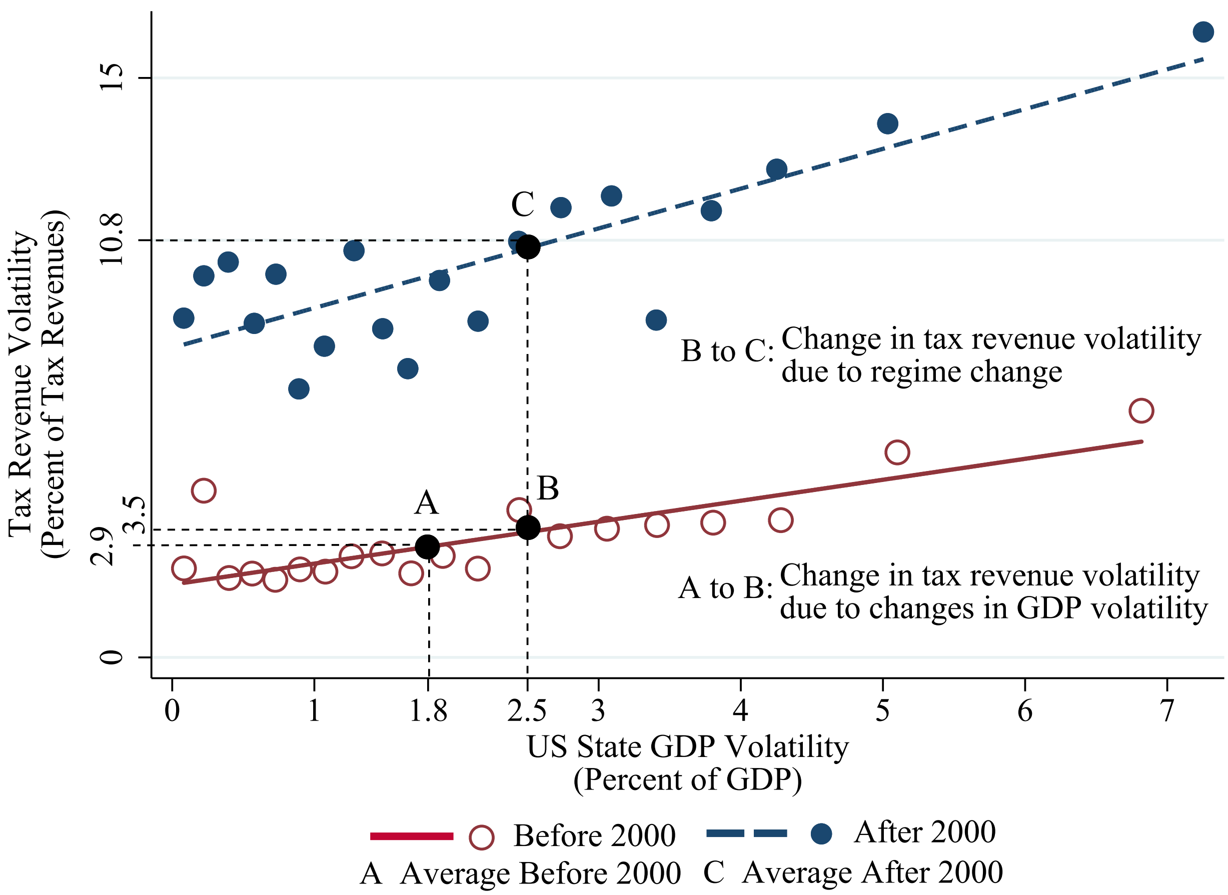
Panel A graphs the residuals of GDP (green dashed line) and state tax revenue (blue solid line) from separate time trends from 1970 to 2014. To calculate the state tax revenue residuals, I first aggregate income, sales, and corporate tax revenues across states. Second, I use a fifth-order polynomial as a time trend and take the residuals from that regression. I follow these steps again for GDP. The graph looks similar if I use a third-order through ninth-order polynomial and a fifth-order polynomial was chosen by the Akaike Information Criterion (AIC). I then scale the residuals by the level of tax revenues or GDP to report the residuals on the same graph as percentage shocks. Panel B graphs residuals of tax revenue (blue solid line) and state expenditures (red dashed line) from 1970 to 2014. I follow the same procedure to calculate state expenditure residuals; aggregating state expenditures across states, regressing state expenditures on a fifth-order polynomial, taking the residuals, and scaling the residuals by tax revenue or expenditures.

A) **State Tax Revenue and GDP Shocks**

B) **State Tax Revenue and Expenditure Shocks**

Figure 2: **State Tax Revenue Volatility and Economic Volatility**

This figure investigates the mapping of state-level GDP volatility to tax revenue volatility using a bin scatter plot. The bin scatter plot groups points into 20 bins. This figure graphs bin scatter plot of tax revenue volatility and state-level GDP volatility before and after 2000 separately. The red hollow circles correspond to points before 2000. Each red dot represents roughly 75 state-year observations. The blue solid circles correspond to points after 2000 and represent roughly 37 state-year observations. The red solid line represents the best fit line for points before 2000 and the blue dashed line is the best fit line for points after 2000. Point A depicts state GDP volatility and tax revenue volatility before 2000 (1.8%, 2.9%). Point B depicts state GDP volatility after 2000 and the tax revenue volatility after 2000 if tax rates and all other factors had remained the same (2.5%, 3.5%). Point C depicts state GDP volatility and tax revenue volatility after 2000 (2.5%, 10.8%). This figure was produced using the binscatter program in stata written by Michael Stepner. Further discussion of this figure occurs in section 3.5.



APPENDIX FOR ONLINE PUBLICATION

Table A.1: **Changes in State Tax Revenue Volatility**

This table reports tax revenue volatility for income, sales, and corporate tax revenues. Panel A reports changes in volatility using residuals from trend, four-year rolling variances, and year-over-year changes. All reported statistics scale estimated volatility by tax revenue to express volatility as a percentage of revenue. Year-over-year changes are calculated as $(x_t - x_{t-1})/x_{t-1}$, the rolling variance uses a four-year window, calculated as $\sqrt{var(x)}$/(Tax Revenues), and the residual method uses deviations from a flexibly estimated state-specific time trend, calculated as $\sqrt{\varepsilon^2}$/(Tax Revenues). Panel B reports the number of states that experienced an increase, decrease, or no change in the volatility of their revenue sources using the residual measure. Data from 1970–2014 were collected by the author from the Book of States, the World Tax Database, the Advisory Commission on Intergovernmental Relations biannual report, and the Tax Foundation.

	Total (1)	Income (2)	Sales (3)	Corporate (4)
Panel A: Change in Volatility				
Residual from Trend				
Before 2000	2.93%	5.12%	2.91%	9.43%
After 2000	10.80%	13.47%	7.66%	28.32%
4-Year Rolling Variance				
Before 2000	7.09%	8.31%	6.13%	11.08%
After 2000	15.34%	17.52%	12.18%	34.93%
Year-over-Year Changes				
Before 2000	5.34%	6.18%	4.49%	9.38%
After 2000	12.77%	12.18%	9.93%	30.11%
Panel B: The Number of States for which Volatility				
Increased	49	43	42	46
Did not change	0	6	5	4
Decreased	1	1	3	0

Table A.2: **Changes in State Economic Uncertainty and Tax Rates**

This table reports the variation in economic uncertainty and tax policy from 1970–2014. Panel A reports the average volatility of state GDP and coincident index from 1970–1999 and 2000-2014. Panel B reports the average, 25th percentile, median, and 75th percentile of income, sales, and corporate tax rates from 1970–1999 and 2000-2014. Panel C reports the number of tax rate changes, increases, and decreases. Panel D reports the number of years where a state increased or decreased a tax rate. Panel E reports the average number of tax changes from 1970–1999 and 2000-2014. Data on tax rates by state from 1970–2014 were collected by the author from the Book of States, the World Tax Database, the Advisory Commission on Intergovernmental Relations biannual report, and the Tax Foundation.

Panel A: Economic Uncertainty	State GDP		Coincident	
	(1)		(2)	
Average 1970–1999	1.8		1.6	
Average 2000–2014	2.3		2.3	
Panel B: Tax Rates	Top inc.	Bottom inc.	Sales	Corporate
	(1)	(2)	(3)	(4)
1970–1999				
Average	6.1	1.9	4.0	6.5
25 percentile	3.0	0.7	3.0	5.0
Median	6.0	2.0	4.0	6.8
75 percentile	8.8	2.8	5.0	8.6
Standard Deviation	1.2	0.5	0.6	0.8
2000–2014				
Average	5.5	2.3	4.9	6.6
25 percentile	4.6	1.0	4.0	6.0
Median	6.0	2.0	5.1	7.0
75 percentile	7.0	3.5	6.0	8.5
Standard Deviation	0.6	0.3	0.2	0.4
Panel C: Observations	Average	Income	Sales	Corporate
With a Change	228	265	170	250
With an Increase	125	111	136	127
With a Decrease	104	154	34	123
Panel D: Years	Average	Income	Sales	Corporate
With an Increase	37	37	37	36
With a Decrease	34	40	24	39
With Both	27	32	19	30
Panel E: Average Number of Changes				
	Average	Income	Sales	Corporate
1970–1999	5.2	11.3	3.7	5.7
2000–2014	4.7	11.3	3.3	4.1

Table A.3: **Economic Regions**

Specifications in Table 4 reports estimates using region-year fixed effects. These specifications test for the sensitivity of the estimates to potential confounding factors. The regions are determined by clustering states based on similarities in the fraction of employment and GDP in each industry. This table reports those regions (4) and divisions (12). The four regions are reported in columns 1–4. Each region is made up of one or more divisions. Those divisions are designated by row. The estimates are also similar if the regions and divisions are those defined by the US Census.

	Region 1 (1)		Region 2 (2)		Region 3 (3)		Region 4 (4)
Division 1	Alabama	Division 5	Indiana	Division 8	California	Division 9	Arizona
	Iowa		Maryland		New York		Colorado
	Kentucky		Minnesota		Texas		Connecticut
	Louisiana		Missouri				
	Oklahoma		Tennessee			Division 10	Alaska
	Oregon		Washington				Maine
	South Carolina		Wisconsin				Vermont
							Wyoming
Division 2	Arkansas	Division 6	Georgia				
	Kansas		Massachusetts			Division 11	Delaware
	Mississippi		Michigan				Montana
	Nebraska		New Jersey				Rhode Island
			North Carolina				
Division 3	North Dakota		Virginia			Division 12	Hawaii
	South Dakota						Idaho
		Division 7	Florida				New Hampshire
Division 4	Nevada		Illinois				New Mexico
	Utah		Ohio				West Virginia
			Pennsylvania				

Table A.4: **Tests for Confounding Factors**

This table reports the decomposition estimates using region-by-year fixed effects, lagged tax rates, and specifications excluding years around the financial crises. The regions in columns (1) and (2) are determined by clustering states based on similarities in the fraction of employment and GDP in each industry. Columns (3) and (4) report specifications with tax rates lagged by one or two years. Columns (5)–(7) exclude the years 2008–2009, 2008–2010, and 2007–2010, respectively. Volatility of revenue and economic variables is calculated as the squared residual from a regression of the variable x and a flexible state-specific time trend. Bootstrapped standard errors (5,000 replications) clustered by state are reported in parentheses below the estimates. Statistical significance at the 10, 5, and 1 percent levels are denoted by *, **, and ***, respectively.

	Regional×Year FE		Tax Rate		Excluding Financial Crisis Years		
	4 Groups	12 Groups	$t-1$	$t-2$	2008–2009	2008–2010	2007–2010
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Income Tax Revenue							
Tax Portfolio	0.640***	0.635***	0.605***	0.616***	0.745***	0.774***	0.702***
	(0.011)	(0.013)	(0.003)	(0.003)	(0.013)	(0.016)	(0.011)
Tax Base	0.217***	0.270***	0.078***	0.063***	0.060***	0.061***	0.149***
	(0.011)	(0.012)	(0.005)	(0.005)	(0.013)	(0.015)	(0.011)
Economic	0.143***	0.095***	0.317***	0.321***	0.196***	0.165***	0.149***
Uncertainty	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.004)	(0.002)
Panel B: Sales Tax Revenue							
Tax Portfolio	0.550***	0.497***	0.533***	0.545***	0.619***	0.662***	0.636***
	(0.006)	(0.008)	(0.003)	(0.003)	(0.008)	(0.010)	(0.007)
Tax Base	0.320***	0.367***	0.095***	0.098***	0.176***	0.168***	0.159***
	(0.006)	(0.007)	(0.005)	(0.005)	(0.009)	(0.011)	(0.008)
Economic	0.130***	0.135***	0.373***	0.357***	0.223***	0.170***	0.204***
Uncertainty	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)	(0.003)	(0.002)
Panel C: Corporate Tax Revenue							
Tax Portfolio	0.108***	0.096***	0.339***	0.349***	0.126***	0.106***	0.169***
	(0.015)	(0.015)	(0.003)	(0.002)	(0.015)	(0.017)	(0.015)
Tax Base	0.782***	0.848***	0.318***	0.318***	0.709***	0.745***	0.682***
	(0.015)	(0.015)	(0.004)	(0.004)	(0.016)	(0.018)	(0.016)
Economic	0.110***	0.056***	0.343***	0.334***	0.166***	0.150***	0.149***
Uncertainty	(0.002)	(0.002)	(0.003)	(0.002)	(0.003)	(0.004)	(0.004)
State Fixed Effects	✓	✓	✓	✓	✓	✓	✓
Year Fixed Effects	✓	✓	✓	✓	✓	✓	✓
Observations	2250	2250	2250	2250	2250	2250	2250

Table A.5: **Sensitivity to Different Orders of Polynomial**

This table reports the decomposition estimates using a third- to ninth-order polynomial. The baseline estimates use a fifth-order polynomial to calculate the residuals that are used to calculate volatility and were determined by the AIC criteria. Volatility of revenue and economic variables is calculated as the squared residual from a regression of the variable x and a flexible state-specific time trend. Bootstrapped standard errors (5,000 replications) clustered by state are reported in parentheses below the estimates. Statistical significance at the 10, 5, and 1 percent levels are denoted by *, **, and ***, respectively.

	3rd	4th	5th	6th	7th	8th	9th
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Income Tax Revenue							
Tax Portfolio	0.728***	0.679***	0.671***	0.683***	0.622***	0.608***	0.614***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)
Tax Base	0.109***	0.157***	0.100***	−0.038***	−0.010***	0.024***	0.004
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)
Economic Uncertainty	0.163***	0.164***	0.229***	0.355***	0.388***	0.368***	0.383***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Panel B: Sales Tax Revenue							
Tax Portfolio	0.642***	0.551***	0.583***	0.574***	0.601***	0.535***	0.483***
	(0.003)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)
Tax Base	0.128***	0.225***	0.157***	0.105***	−0.038***	0.045***	0.044***
	(0.004)	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)
Economic Uncertainty	0.230***	0.224***	0.260***	0.322***	0.438***	0.420***	0.474***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Panel C: Corporate Tax Revenue							
Tax Portfolio	0.142***	0.153***	0.153***	0.151***	0.127***	0.164***	0.200***
	(0.004)	(0.005)	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)
Tax Base	0.720***	0.701***	0.669***	0.608***	0.599***	0.486***	0.606***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Economic Uncertainty	0.138***	0.146***	0.178***	0.241***	0.275***	0.351***	0.195***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
State Fixed Effects	✓	✓	✓	✓	✓	✓	✓
Year Fixed Effects	✓	✓	✓	✓	✓	✓	✓
Observations	2250	2250	2250	2250	2250	2250	2250

Table A.6: **Sensitivity to Different Before and After Years**

This table reports the decomposition estimates using break years in a three-year window on either side of 2000. The baseline estimates use 2000 as the break year based on structural break tests. Volatility of revenue and economic variables is calculated as the squared residual from a regression of the variable x and a flexible state-specific time trend. Bootstrapped standard errors (5,000 replications) clustered by state are reported in parentheses below the estimates. Statistical significance at the 10, 5, and 1 percent levels are denoted by *, **, and ***, respectively.

	1997	1998	1999	2000	2001	2002	2003
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Income Tax Revenue							
Tax Portfolio	0.707***	0.666***	0.662***	0.671***	0.659***	0.676***	0.675***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)
Tax Base	0.065***	0.080***	0.101***	0.100***	0.089***	0.048***	0.008***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)
Economic	0.228***	0.254***	0.237***	0.229***	0.252***	0.276***	0.318***
Uncertainty	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Panel B: Sales Tax Revenue							
Tax Portfolio	0.631***	0.606***	0.591***	0.583***	0.590***	0.605***	0.578***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Tax Base	0.101***	0.119***	0.145***	0.157***	0.133***	0.107***	0.109***
	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Economic	0.268***	0.275***	0.263***	0.260***	0.277***	0.288***	0.313***
Uncertainty	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Panel C: Corporate Tax Revenue							
Tax Portfolio	0.222***	0.210***	0.181***	0.153***	0.153***	0.171***	0.163***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)
Tax Base	0.600***	0.604***	0.642***	0.669***	0.622***	0.566***	0.519***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Economic	0.178***	0.186***	0.177***	0.178***	0.226***	0.263***	0.318***
Uncertainty	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
State Fixed Effects	✓	✓	✓	✓	✓	✓	✓
Year Fixed Effects	✓	✓	✓	✓	✓	✓	✓
Observations	2250	2250	2250	2250	2250	2250	2250

Table A.7: **Coefficients From Baseline Decomposition**

This table reports the coefficients from the baseline decomposition. Standard errors are reported in parentheses below the estimates. Statistical significance at the 10, 5, and 1 percent levels are denoted by *, **, and ***, respectively.

	Income		Sales		Corporate			
	β_{pre}	β_{post}	β_{pre}	β_{post}	β_{pre}	β_{post}	x_{pre}	x_{post}
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log tax rates squared								
Top income	1.865***	4.958***	-0.339***	0.393***	-0.605***	0.994***	3.169	3.160
	(0.167)	(0.331)	(0.130)	(0.140)	(0.152)	(0.339)		
Bottom income	1.700***	0.417	0.927***	-0.920***	1.526***	-0.193	1.458	1.689
	(0.309)	(0.428)	(0.241)	(0.314)	(0.281)	(0.453)		
Sales	-0.651***	-0.507	8.438***	7.865***	0.585**	0.796**	2.717	3.067
	(0.252)	(0.341)	(0.197)	(0.262)	(0.230)	(0.357)		
Corporate	3.834***	3.170***	0.181	0.620***	4.403***	4.166***	3.522	3.571
	(0.209)	(0.325)	(0.163)	(0.225)	(0.190)	(0.332)		
Tax rates squared								
Top income	-0.038***	-0.108***	-0.001	-0.016*	-0.011***	-0.049***	54.794	39.926
	(0.004)	(0.012)	(0.003)	(0.009)	(0.003)	(0.012)		
Bottom income	-0.165***	-0.056	-0.120***	0.035	-0.109***	-0.001	6.342	8.684
	(0.033)	(0.043)	(0.026)	(0.032)	(0.030)	(0.046)		
Sales	0.003	0.014	-0.338***	-0.214***	-0.117***	-0.107***	19.689	28.101
	(0.022)	(0.026)	(0.017)	(0.019)	(0.020)	(0.028)		
Corporate	-0.040***	-0.051***	-0.017***	-0.045***	-0.049***	-0.057***	51.998	52.56
	(0.007)	(0.011)	(0.005)	(0.008)	(0.006)	(0.011)		
Log economic volatility								
State GDP	0.218***	0.025	0.225***	0.187***	0.161***	-0.023	29.02	29.135
	(0.052)	(0.072)	(0.040)	(0.053)	(0.047)	(0.076)		
Personal income	0.114**	0.275***	0.174***	0.222***	-0.018	0.131*	26.948	28.773
	(0.052)	(0.069)	(0.041)	(0.050)	(0.048)	(0.072)		
Population	2.435***	2.024***	1.817***	1.739***	2.530***	2.142***	0.473	0.595
	(0.318)	(0.360)	(0.249)	(0.257)	(0.290)	(0.379)		
Constant	-7.558***	-8.281***	-9.215***	-9.719***	0.875	3.574		
	(1.772)	(2.402)	(1.384)	(1.742)	(1.616)	(2.523)		
State Fixed Effects	✓	✓	✓	✓	✓	✓		
Year Fixed Effects	✓	✓	✓	✓	✓	✓		
Adj. R-Square	0.603	0.685	0.746	0.819	0.501	0.447		
Observations	1600	650	1600	650	1600	650		

Table A.8: **State and Year Variation**

This table reports the coefficients from the income tax revenue volatility with and without state and year fixed effects to demonstrate the variation used to estimate these coefficients. Standard errors are reported in parentheses below the estimates. Statistical significance at the 10, 5, and 1 percent levels are denoted by *, **, and ***, respectively.

	Income							
	β_{pre}				β_{post}			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log tax rates squared								
Top income	1.983***	1.947***	1.821***	1.865***	4.504***	4.567***	4.889***	4.958***
	(0.152)	(0.148)	(0.172)	(0.167)	(0.291)	(0.294)	(0.332)	(0.331)
Bottom income	1.140***	1.176***	1.727***	1.700***	1.388***	1.295***	0.490	0.417
	(0.253)	(0.252)	(0.311)	(0.309)	(0.358)	(0.365)	(0.427)	(0.428)
Sales	-1.317***	-1.262***	-0.558**	-0.651***	-1.165***	-1.162***	-0.450	-0.507
	(0.250)	(0.246)	(0.265)	(0.252)	(0.341)	(0.348)	(0.341)	(0.341)
Corporate	3.361***	3.373***	3.837***	3.834***	2.832***	2.854***	3.168***	3.170***
	(0.187)	(0.187)	(0.210)	(0.209)	(0.272)	(0.279)	(0.322)	(0.325)
Tax rates squared								
Top income	-0.030***	-0.029***	-0.037***	-0.038***	-0.075***	-0.076***	-0.107***	-0.108***
	(0.003)	(0.003)	(0.004)	(0.004)	(0.010)	(0.010)	(0.012)	(0.012)
Bottom income	-0.080***	-0.086***	-0.169***	-0.165***	-0.165***	-0.155***	-0.063	-0.056
	(0.028)	(0.028)	(0.033)	(0.033)	(0.038)	(0.039)	(0.043)	(0.043)
Sales	0.081***	0.072***	-0.007	0.003	0.056**	0.057**	0.009	0.014
	(0.022)	(0.021)	(0.024)	(0.022)	(0.026)	(0.026)	(0.027)	(0.026)
Corporate	-0.018***	-0.019***	-0.040***	-0.040***	-0.035***	-0.035***	-0.051***	-0.051***
	(0.006)	(0.006)	(0.007)	(0.007)	(0.009)	(0.009)	(0.011)	(0.011)
Log economic volatility								
State GDP	0.132***	0.123***	0.230***	0.218***	0.020	-0.021	0.088	0.025
	(0.044)	(0.041)	(0.054)	(0.052)	(0.061)	(0.059)	(0.075)	(0.072)
Personal income	-0.010	0.013	0.084	0.114**	0.054	0.172***	0.216***	0.275***
	(0.045)	(0.042)	(0.055)	(0.052)	(0.066)	(0.057)	(0.078)	(0.069)
Population	4.674***	4.595***	2.464***	2.435***	0.047	-0.033	2.024***	2.024***
	(0.649)	(0.640)	(0.327)	(0.318)	(0.757)	(0.774)	(0.381)	(0.360)
State Fixed Effects		✓		✓		✓		✓
Year Fixed Effects			✓	✓			✓	✓
Adj. R-Square	0.747	0.747	0.599	0.603	0.806	0.795	0.692	0.685
Observations	1600	1600	1600	1600	650	650	650	650

Table A.9: **Alternative Volatility Measure**

This table reports estimates based on Oaxaca-Blinder decomposition. Columns (1) through (3) report the decomposition of income, sales, and corporate tax revenue volatility, respectively, and columns (4) through (6) report the decomposition of the associated co-volatilities. The contribution in percentage of differences in tax rates, economic uncertainty, and tax bases for each tax base is based on equation (9), where mean characteristics before 2000 are denoted by the subscript 0 and after 2000 by the subscript 1 and reported in Table A.2. All specifications include state and year fixed effects. Volatility of revenue is calculated as the squared residual divided by tax revenues, $\varepsilon^2_{i,t}/(\text{Tax Revenue}_t)$ from a regression of revenues and a flexible state-specific time trend. Bootstrapped standard errors (5,000 replications) clustered by state are reported in parentheses below the estimates. Statistical significance at the 10, 5, and 1 percent levels are denoted by *, **, and ***, respectively.

	Volatility			Co-volatility		
	Income (1)	Sales (2)	Corporate (3)	(Inc., Corp.) (4)	(Inc., Sales) (5)	(Sales, Corp.) (6)
Tax Portfolio	0.707***	0.759***	0.326***	0.696***	0.662***	0.652***
	(0.005)	(0.003)	(0.004)	(0.001)	(0.001)	(0.001)
Tax Base	0.067***	0.031***	0.577***	0.002***	0.062***	0.030***
	(0.005)	(0.003)	(0.004)	(0.001)	(0.001)	(0.001)
Economic	0.226***	0.210***	0.097***	0.302***	0.277***	0.318***
Uncertainty	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
State Fixed Effects	✓	✓	✓	✓	✓	✓
Year Fixed Effects	✓	✓	✓	✓	✓	✓
Observations	2250	2250	2250	2250	2250	2250

Table A.10: **Motor Fuel Tax Revenue Volatility**

This table reports descriptive statistics and a decomposition of tax revenue volatility for motor fuel tax. Data comes from State & Local Government Finance Data Query System. http://slfdqs.taxpolicycenter.org/pages.cfm. The Urban Institute-Brookings Institution Tax Policy Center and from U.S. Census Bureau, Annual Survey of State and Local Government Finances, Government Finances, Volume 4, and Census of Governments (1977–2015). Panel A reports the tax rate and volatility before and after 2000. Panel B reports the decomposition into tax rate, tax base, and economic factors as in the baseline estimation. Bootstrapped standard errors (5,000 replications) clustered by state are reported in parentheses below the estimates. Statistical significance at the 10, 5, and 1 percent levels are denoted by *, **, and ***, respectively.

Panel A: Descriptive Statistics			
	Before 2000	After 2000	Change
	(1)	(2)	(3)
Tax Rate	16.55	20.14	3.59
Volatility	18.24	18.70	0.46

Panel B: Decomposition	
	Motor Fuel
	(1)
Tax Portfolio	0.503***
	(0.020)
Tax Base	0.031
	(0.070)
Economic Uncertainty	0.467***
	(0.064)
State Fixed Effects	✓
Year Fixed Effects	✓
Observations	2250

Table A.11: **Alternative Decomposition**

This table reports a decomposition of tax revenue volatility under an alternative decomposition derived in Appendix B.2. The factors in the alternative decomposition are the variance of tax rates, the tax base, the covariance of tax rates and economic factors. Bootstrapped standard errors (5,000 replications) clustered by state are reported in parentheses below the estimates. Statistical significance at the 10, 5, and 1 percent levels are denoted by *, **, and ***, respectively.

	Volatility		
	Income	Sales	Corporate
	(1)	(2)	(3)
Variance(log(Tax Rates))	0.029	0.181	0.057
	(1.198)	(0.695)	(1.610)
Tax Base	1.11	0.434	0.435
	(1.360)	(0.500)	(4.332)
Covariance	0.634	0.035	0.316
	(0.495)	(0.326)	(1.668)
Economic	-0.773	0.349	0.192
	(0.805)	(0.586)	(6.651)
State Fixed Effects	✓	✓	✓
Year Fixed Effects	✓	✓	✓
Observations	200	200	200

Figure A.1: **Different Measures of Tax Revenue Volatility**

This figure graphs aggregate state tax revenue volatility as a precentage of revenues. Tax revenue volatility measured as year-over-year changes is given by a blue solid line. Tax revenue volatility measured as a four year rolling variance is given by a red dashed line. Tax revenue volatility measured as a squared residual is given by a green dotted line. To compare these measures, the measures are put as a percentage of revenues. The year-over-year measure is calculated as $(x_t - x_{t-1})/x_{t-1}$. The four-year rolling variance is calculated as $\sqrt{var(x)}$/(Tax Revenues) over this window and the squared residual measure is calculated as $\sqrt{\varepsilon^2}$/(Tax Revenues).

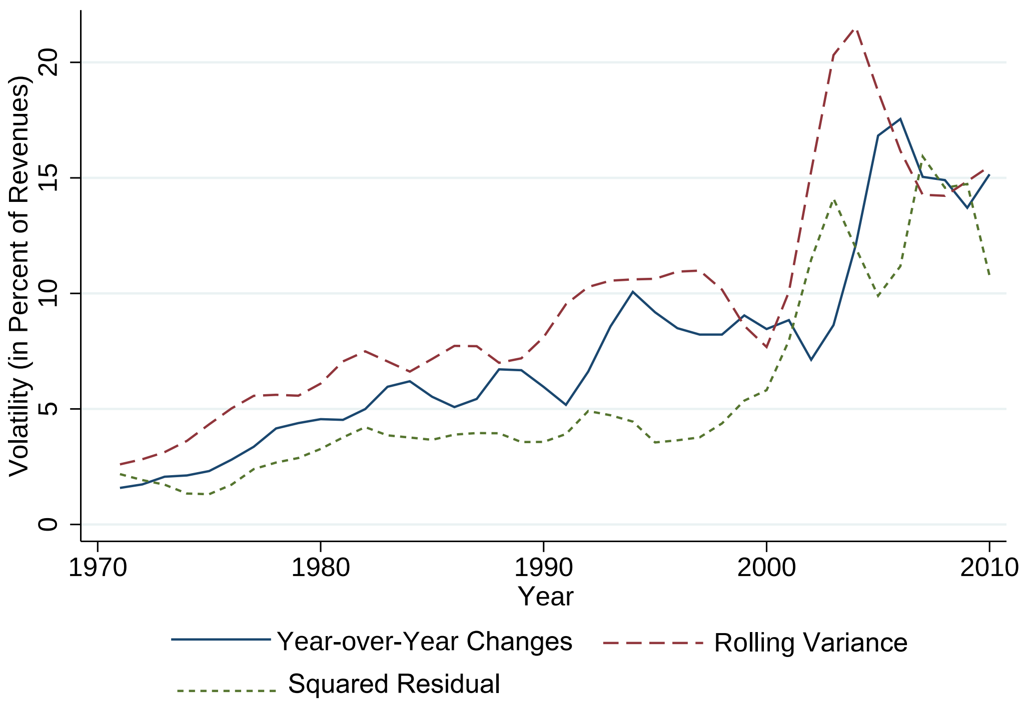
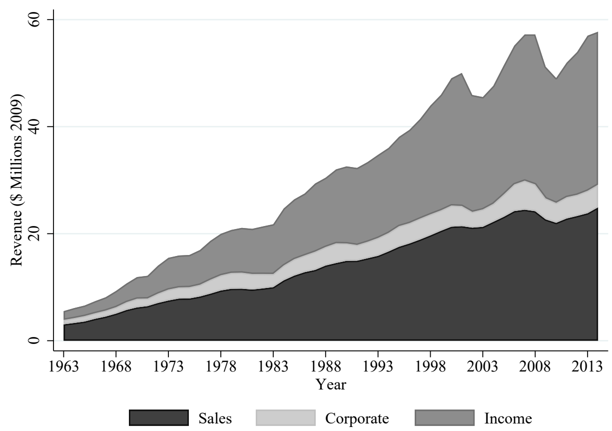


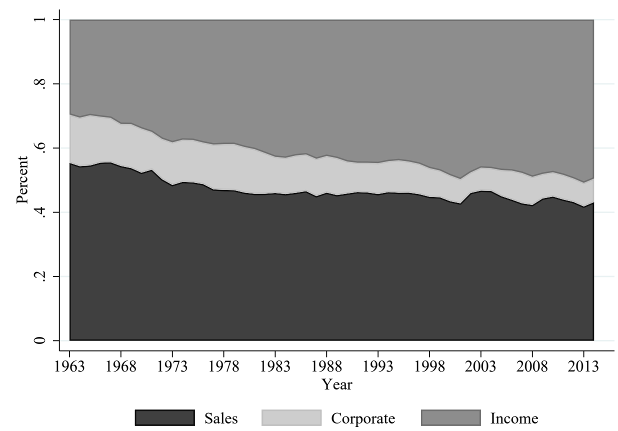
Figure A.2: **Changes in State Tax Portfolios**

This figure reports changes in state tax portfolios. Panel A reports the change in sales, corporate, and income tax revenue in millions of 2009 dollars. Panel B reports the change in percentage of sales, corporate, and income tax revenue. Panel C reports the percentage of tax revenue from income taxes on the horizontal axis with all 50 states on the vertical axis ranked by their income tax reliance in 1970. The $x's$ denote income tax reliance in 1970 and the $o's$ denote income tax reliance in 2000. Horizontal differences between $o's$ and $x's$ denote the change in income tax reliance for each state between 1970 and 2000.

A) **Change Tax Revenue**



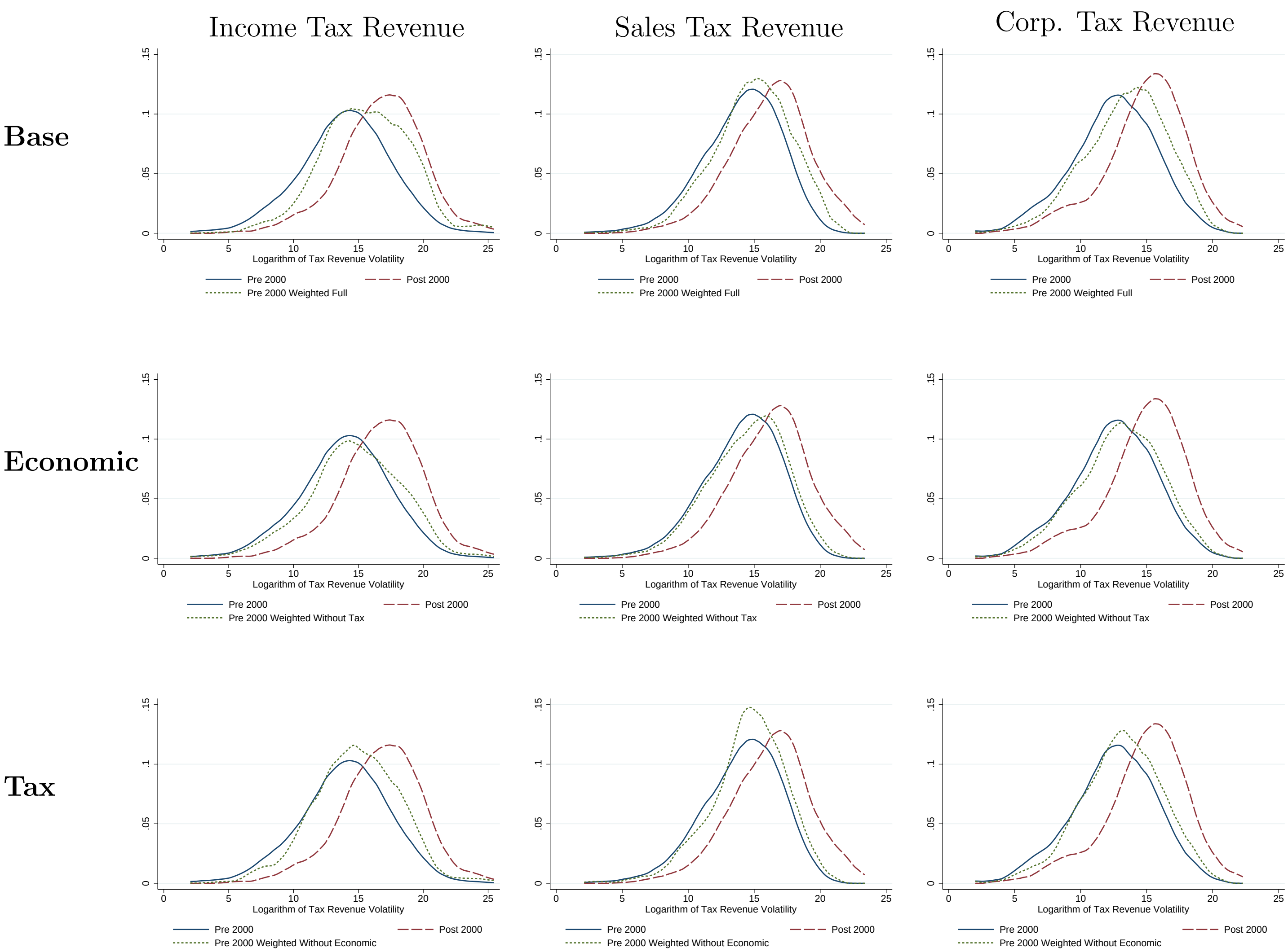
B) **Change in Reliance**



C) **Individual State Changes**

Figure A.3: **Differences in Tax Revenue Volatility**

This figure graphs the distribution of log tax revenue volatility for the income, sales, and corporate tax. The solid blue line is the distribution of volatility before 2000, and the dashed red line is the distribution of volatility after 2000. The green dashed line graphs the distribution before 2000, weighted to have the same observable characteristics as the distribution after 2000. The first row graphs the weighted distribution using all characteristics. The difference between the weighted distribution and the post-2000 distribution is attributed to differences in tax bases, while the difference between the weighted distribution and the pre-2000 distribution is attributed to observable characteristics: tax policy and economic uncertainty. Rows 2 and 3 decompose the observable characteristics by graphing the weighted distribution, leaving out tax variables (row 2) and economic variables (row 3).



Appendix A Data

Appendix A.1 Measuring Volatility

In this paper, I consider three measures of volatility: squared residuals, year-over-year changes, and a four-year rolling variance. Each of the volatility measures I consider can be thought of as a difference between observed values and an expected value. The year-over-year measure uses the difference between the observed value for a single year and the expected value, which is the value in the previous year. The four-year rolling variance measure uses the average difference between observed values over four years and the expected value, which is the average value over those years. The residual measure uses the difference between the observed value and the expected value from a flexibly estimated state-specific time trend using the Akaike information criterion (AIC), which is flexible and data-driven.

The benefits of using a flexible and data-driven expected value are larger when the variables of interest have strong time trends. The residual volatility measure distinguishes between shocks and time trends because the time trend is incorporated into its predicted value. In contrast, the year-over-year and four-year rolling variance measures do not distinguish shocks separately from time trends. For example, a large increase in revenues between two years could be due to a large shock or a steeper trend. The year-over-year measure does not distinguish these two possibilities and quantifies volatility as the difference between the two years. The variables of interest in this study, such as tax revenues and GDP, have strong time trends. This suggests that residual volatility is a better measure of unexpected shocks. Because of the strong time trends, the residual method is also a more conservative measure of volatility.

Table A.1 reports that tax revenue volatility increased in each of the major revenue sources (income, sales, and corporate). Column (2) reports that volatility of income taxes increased from an average of 5.12% before 2000 to 13.47% after 2000, using the residual measure. Columns (3) and (4) report that the sales and corporate tax revenues experienced a 4.55 and 18.99 percentage point increase in volatility after 2000, using the residual measure. The rolling-variance and year-over-year measures of volatility provide similar increases in volatility after 2000. Panel B of Table A.1 reports that across all three major revenue sources, almost every state that relies on a given source experienced an increase in volatility.

The evidence in Table A.1 suggests that explanations that are specific to one state or revenue source cannot fully explain the increase in tax revenue volatility. For example, the increased importance of capital gain income in California in the late 1990s and 2000s is a potentially important factor in the volatility increase in California's income tax revenue, but it cannot explain the broader increases across states and revenue sources. The decomposition method, explained in Section 3, captures all other factors, such as increased importance of capital gain income, but the broad increases across states and revenue sources suggest that broad changes in tax policy and economic uncertainty play a role.

Appendix A.2 Variation in Tax Rates

This section investigates the variation in tax rates that is used in the decomposition to quantify the contribution of changes in tax rates to the increase in tax revenue exposure to GDP volatility and ultimately tax revenue volatility. Panels B through E of Table A.2 report the variation in tax rates from 1970 through 2014. Panel B reports the average, median, and 25th and 75th percentiles of the top income, bottom income, sales, and corporate tax rate before and after 2000 (defined as 1970–1999 and 2000–2014). The average bottom income, sales, and corporate tax rates increased from 1.9, 4.0, and 6.5 before 2000 to 2.3, 4.9, and 6.6 after 2000, respectively. The average top income tax rate decreased from 6.1 before 2000 to 5.5 after 2000, though the median remained unchanged at 6.0 and the 25th percentile increased from 3.0 to 4.6.

Panels C and D demonstrate that while any given state tax rate does not change that often there is variation across state-year observations. Panel C of Table A.2 shows that from 1970 through 2014 there were 265 state-year observations with an income tax rate change (column 2) and 170 and 250 state-year observations with a sales and corporate tax rate change, respectively (columns 3 and 4). The number of income, sales, and corporate tax rate changes (row 1), increases (row 2), and decreases (row 3) are relatively similar. Panel D of Table A.2 shows that from 1970 through 2014 there were 37 years in which at least one state increased their income tax rate, 40 years in which at least one state decreased their income tax rate, and 32 years in which at least one state increased and at least one state decreased their income tax rates.

Panel E of Table A.2 shows that there is very little difference in the average number of tax rate changes before and after 2000. For example, Panel B reports the within-state standard deviation of tax rates is smaller after 2000 than before. Similarly, column (3) of Panel E reports 3.7 states, on average, changed their sales tax rate before 2000 and 3.3 states after 2000. This evidence suggests that tax revenue volatility did not change because states changed their tax rates more after 2000. For this reason, the empirical analysis focuses on how differences in tax rates before and after 2000 affected tax revenue volatility because states did not change their tax rates more often after 2000.

Appendix A.3 Variation in Economic Uncertainty

This section investigates the variation in economic uncertainty that is used in the decomposition to quantify its contribution to tax revenue volatility. Tax revenue volatility certainly increased in the 2000s due to the economic uncertainty of the dot-com bubble, the housing bubble, and the recessions in 2001 and 2008. Panel A of Table A.2 reports the change in economic uncertainty, measured as the volatility of state GDP in column (1) and the volatility of the coincident index in column (2). The average state GDP volatility increased from 1.8% in the 1970–1999 period to 2.3% in the 2000–2014 period. Similarly, the average coincident index volatility increased from 1.6% in the 1970–1999 period to 2.3% in the 2000–2014 period.

Panel A of Figure 1 shows the relationship between state tax revenue shocks and state GDP shocks, represented as residuals from a time trend. Before 2000, state tax revenue shocks, as a percentage, are roughly the same magnitude as state GDP shocks. After 2000, state tax revenue shocks are substantially larger than state GDP shocks. The differential increase in tax revenue volatility suggests that increased economic uncertainty after 2000 cannot fully explain the increase in tax revenue volatility.

Appendix A.4 Changes in State Tax Policies

Figure A.2 reports the increase and shift in state tax revenues from sales taxes toward income taxes. Panel A shows sales, corporate, and income tax revenues increased from 1963 to 2014, with larger increases in income and sales relative to corporate revenues. Panel B shows that the percentage of revenues from sales and corporations decreased and income revenues increased. Specifically, income tax revenues went from roughly 30% to 50% between 1963 and 2014.

Panel C shows that the shift toward income tax revenues is true for most states. On the horizontal axis is the percent of tax revenues from income taxes in 1970 and 2000, denoted by an x and an o, respectively. The average in 1970 and 2000 are denoted by vertical dashed lines, black for 1970 and red for 2000. The vertical axis stacks states by their income tax reliance in 1970, those with zero income tax revenue at the bottom and those with the highest percentage coming from income tax revenues at the top. Shifts toward income tax revenues are given by the $o's$ being to the right of the $x's$, which is the general pattern. Some states decreased their reliance on income taxes and that is denoted by an x being further to the right than the corresponding o. The largest shift is for states that had a low reliance in 1970, where many states went from income tax revenues of less than 20% of their revenues to 50% or more.

Appendix A.5 Regions

Table A.3 reports the economic regions used in the sensitivity analysis in Table 4. The fifty states are grouped into 12 divisions which then make up 4 regions. The states are grouped based on the similarity of their economies to control for potential industry-specific shocks. Specifically, I use the cluster command in stata that, "attempts to determine the natural groupings (or clusters) of observations." I use the fraction of employment and GDP by industry (3-digit NAICS codes). The divisions and regions do not have to have an even number of states in them. In particular, region 3 consists of only one division that has three states, California, New York, and Texas. In contrast, region 2 consists of three divisions and 17 states. The groupings look reasonable. For example, states that are both geographically close and otherwise seem similar are grouped together; see Wisconsin and Minnesota, North and South Dakota, Nevada and Utah, Nebraska and Kansas.

The advantage of grouping states based on economic activity is that it provides a better test for confounding factors than geographic regions—though there is considerable overlap. For example, Vermont and New York State geographically are very close, but their economic activity is relatively different. In terms of economies, Vermont is more similar to Wyoming, Maine, and Alaska and may experience similar shocks to those states as opposed to New

York.

In this context, using the economic or geographic clusters defined by the Census provide very similar results. One reason for this is that there is considerable overlap between those groups. Another reason is that in this context there is not a lot of scope for unobserved shocks to impact tax revenue volatility in a way that is not captured by state GDP, state personal income, or population.

Appendix B Additional Specifications

Appendix B.1 Sensitivity of Estimates

This section supplements section 5 with additional tables and figures. Tables A.4, A.5, A.6, and A.9 provide estimates excluding the years of the financial crisis, investigating conflating factors, include estimates for a wider range of polynomials and structural break years, and with a different definition of volatility. Figure A.3 provides graphical evidence of the nonparametric decomposition.

Table A.4 reports estimates with region by year fixed effects in columns (1) and (2). The regions are determined by clustering states based on similarities in the fraction of employment and GDP in each industry. Column (1) reports the estimates with 4 regions and column (2) with 12.[40] The decomposition estimates are similar with 4 and 12 regions, reported in columns 1 and 2, respectively. For example, the estimates of how much changes in tax rates explain of the increase in income tax revenue volatility (reported in Panel A) is 64% using 4 or 12 groups. Columns (3) and (4) report estimates with one- and two-year lagged tax rates. These estimates account for potential simultaneity of tax rate choice and tax revenue volatility. The estimates in columns (3) and (4) are similar to each other and to the baseline results in Table 2. For example, the estimates of how much tax rates explain of the increase in income tax revenue volatility (reported in Panel A) is 61% and 62% with one- and two-year lagged values, which is similar to the 67% baseline estimate.

Columns (5) through (7) of Table A.4 report decomposition estimates excluding different sets of years around the financial crisis. The years 2008 and 2009 are excluded in column (5), 2008 through 2010 are excluded in column (6), and 2007 through 2010 are excluded in column (7). The estimates are similar to the baseline estimates and suggest a slightly higher amount of volatility due to tax rates and less due to economic uncertainty, which is predictable given that these specifications exclude the years of extreme economic uncertainty.

Table A.5 reports the decomposition estimates are not sensitive to the time trend used to calculate the residual measure of volatility. Columns (1) through (7) report estimates using a 3rd through 9th order polynomial. The estimates are stable across these different specifications. For example, the estimates of how much tax rates explain of the increase in income tax revenue (Panel A) ranges from 73% (column 1) to 61% (columns 6 and 7).

Table A.6 reports the decomposition estimates are not sensitive to the sample years

[40] The estimates are also similar if the groups are given by the four census regions or the nine census divisions.

defined as before and after. Columns (1) through (7) report estimates using break years between 1997 and 2003, a three year window around 2000, which is used in the baseline estimates. The estimates of how much tax rates explain of the increase in income tax revenue (Panel A) ranges from 71% (column 1) to 66% (columns 3 and 5).

Figure A.3 graphs the distribution of log tax revenue volatility for the income, sales, and corporate tax. The solid blue line is the distribution of volatility before 2000, and the dashed red line is the distribution of volatility after 2000. Note that the distribution after 2000 is shifted considerably to the right, due to increased tax revenue volatility. The green dashed line graphs the distribution before 2000, which is weighted to have the same observable characteristics as the distribution after 2000. The first row graphs the weighted distribution using all characteristics. The difference between the weighted distribution and the post-2000 distribution is attributed to differences in tax bases, while the difference between the weighted distribution and the pre-2000 distribution is attributed to observable characteristics: tax rates and economic uncertainty. Rows 2 and 3 decompose the observable characteristics by graphing the weighted distribution, leaving out tax variables (row 2) and economic variables (row 3). The weighted distribution in the third row is shifted more to the right than the distributions in the second row, which suggests that tax variables explain more of the increase in distribution than economic variables.

Table A.9 reports estimates using measuring volatility as the residuals from a flexible state-specific time trend, calculated as $\sqrt{\varepsilon^2}/(\text{Tax Revenues}_t)$. The baseline estimates measure volatility as $\sqrt{\varepsilon^2}$ to avoid complications in interpretation between changes in the numerator and denominator. The estimates are similar using this different measure of volatility. In particular, the estimates suggest tax rate changes explain 70% of the increase in income tax revenue volatility, which is similar to the 67% baseline estimate.

Appendix B.2 Alternative Derivations

The decomposition in the text relies on the assumption that changes in tax rates are not an important determinant of the volatility of tax revenue volatility. For example, if state governments changed tax rates a lot, then this could increase tax revenue volatility. In practice, however, states do not change their tax rates that often; on average 5.2 changes per state per revenue source from 1970–1990 (Panel E of Table A.2). More importantly, the number of times states changed their tax rate is similar in both periods. Finally, I find no evidence that states are changing their tax rates in response to tax revenue volatility, which I test for by replacing concurrent tax rates with lagged values (see Column 9 of Table 4 and Columns 3 and 4 of Table A.4). For these reasons, the analysis in the text focuses instead on how changing the reliance of tax revenue sources change the overall tax revenue volatility.

This section derives a decomposition allowing for the volatility of tax rates to impact the volatility of tax revenues, despite the evidence to the contrary. Ultimately, the estimates from this decomposition corroborates the other evidence that the volatility of tax rates does not explain the increase in tax revenue volatility observed in the data (see Table A.11).

We start with the same equation as in the text, equation (1), that relates tax revenue source j, in state s, and year t to tax rates and tax bases Total tax revenues are therefore a weighted combination of tax bases, where the weights are the tax rates,

$$R_{j,s,t} = \sum_j \tau_j B_{j,s,t}(\boldsymbol{\tau}, \boldsymbol{x}). \tag{10}$$

The volatility of tax revenue source j, therefore, can be written as

$$\sigma^2(R_{j,s,t}) = \tau_{j,s,t}^2 \sigma^2(B_{j,s,t}(\boldsymbol{\tau}, \boldsymbol{x})), \tag{11}$$

which is equation (3) in the text. Alternatively, the variance of the log of tax revenues could be written as,

$$var(log(R_{j,s,t})) = var(log(\tau_{j,s,t})) + var(log(B_{j,s,t})) + 2cov(log(\tau_{j,s,t}), log(B_{j,s,t})). \tag{12}$$

At this point, some approximation is necessary because the tax base is unknown. Fortunately, the variables that determine the tax base are known—notably tax rates and economic conditions. I use different approximations given different models,

$$\begin{aligned} log(\sigma^2(B_{j,s,t}(\boldsymbol{\tau}, \boldsymbol{x}))) &= \alpha + (\gamma_j - 2)log(\tau_{j,s,t}) + \sum_{i \neq j} \gamma_i log(\tau_{i,s,t}) \qquad (13) \\ &+ \sum_k \delta_k log(\sigma^2(x_{k,s,t})) + \lambda_s + \lambda_t + \varepsilon_{j,s,t} \\ log(B_{j,s,t}) &\approx \beta_0 + \beta_1 log(\tau_{j,s,t}) + \beta_2 log(x_{k,s,t}) + \eta_{j,s,t}. \qquad (14) \end{aligned}$$

The first approximation is from the text, given in equation (5), and is paired with the model that assumes that the tax rate is given from equation (11). The second approximation is paired with the alternative calculation given in equation (12). In this case, the variance of the log of the tax base and the covariance of the log of the tax rate and the log of the tax base are given by

$$var(log(B_{j,s,t})) = \beta_1^2 var(log(\tau_{j,s,t})) + \beta_2^2 var(log(x_{k,s,t})) + 2\beta_1\beta_2 cov(log(\tau_{j,s,t}), log(x_{k,s,t})) \tag{15}$$

$$cov(log(\tau_{j,s,t}), log(B_{j,s,t})) = \beta_1 var(log(\tau_{j,s,t})) + \beta_2 cov(log(\tau_{j,s,t}), log(x_{k,s,t})). \tag{16}$$

Putting these approximations back into the model produces an econometric model for either the log of tax revenue volatility or the volatility of the log of tax revenues,

$$log(\sigma^2(R_{j,s,t})) = \alpha + \sum_j \gamma_j log(\tau_{j,s,t}) + \sum_k \delta_k log(\sigma^2(x_{k,s,t})) + \lambda_s + \lambda_t + \varepsilon_{j,s,t}. \tag{17}$$

$$\begin{aligned} var(log(R_{j,s,t})) &= b_1 var(log(\tau_{j,s,t})) + b_2 var(log(x_{k,s,t})) \qquad (18) \\ &+ b_3 cov(log(\tau_{j,s,t}), log(x_{k,s,t})) + \eta_{j,s,t}, \end{aligned}$$

where $b_1 = 1 + \beta_1 + \beta_1^2$, $b_2 = \beta_2^2$, and $b_3 = \beta_2 + 2\beta_1\beta_2$.

The first equation is derived from combining the log of the volatility of tax revenue, given in equation (11), and the first approximation given in equation (14). This equation replicates equation (6) in the text in giving the log of the volatility of tax revenue as a function of tax rates and volatility of economic conditions.

The second equation relates the variance of the log of tax revenues with the variance of the log of tax rates, the variance of the log of economic conditions, and the co-variance of the log of tax rates and the log of economic conditions. All of the right hand side variables are observed in the data. One practical issue with this derivation, however, is that these variables are observed once for each state before 2000 and once for each state after 2000. This reduces the sample size from 2250 (state-year observations) to 200. Another practical limitation of this method is that it limits the amount of variables that can be included, because the variance and covariance matrix expands quickly.

Table A.11 reports the decomposition estimates using this alternative derivation. The variance of tax rates and economic conditions explains almost none of the increase in the variance of tax revenue. Almost all of the change in the variance of tax revenue in this decomposition is explained by changes in the tax base and the covariance of tax rates and economic conditions.

Appendix B.3 Coefficients and Panel Data Variation

The coefficients in equation (6) are estimated using panel data from 50 states and the years 1970 to 2014. Table A.7 reports the coefficients from the baseline decomposition in Table 2. These coefficients are used to quantify the contribution of different factors to the changes in tax revenue volatility according to the derivations in section 3.4.

The use of state- and year-fixed effects control for potential confounding factors. For example, state-fixed effects control for idiosyncratic unobserved state factors that are contributing to tax revenue volatility and if they are correlated with tax rates or economic volatility would otherwise bias those estimates and the decomposition. These confounding factors are unlikely to be of practical importance in this setting because the relationship between tax revenue volatility and the independent variables are based on an accounting identity that tax revenues equal the tax rate times the tax base. Table A.8 reports coefficients from the regression of income tax revenue volatility on the baseline tax and economic factors with and without the state and year fixed effects to investigate the practical importance of these confounding factors.

Columns 1–4 of Table A.8 report estimates of the regression for years before 2000 and columns 5–8 report estimates for the years after 2000. Columns 1 and 5 report estimates without state- and year-fixed effects. Columns 2 and 6 include state fixed effects only, columns 3 and 7 include year fixed effects only, and columns 4 and 8 report the baseline estimates with state and year fixed effects. The estimates are relatively similar across these specifications. For the log of the top income tax rate, the estimates are 1.983, 1.947, 1.821, and 1.865. Other coefficients vary more, especially those that are not statistically significant in the baseline specification. The decomposition estimates, however, are relatively insensitive to the use of state and year fixed effects. These estimates suggest that the model captures the important factors that explain tax revenue volatility and that there may not be much scope for omitted variables.

Appendix B.4 Additional Revenue Sources

In addition to income, sales, and corporate tax revenues, states rely on intergovernmental transfers from the federal government, taxes on motor fuel, and other sources. An exploration of these sources is outside the scope of this paper but could provide novel insights. For example, there are important questions about federalism in understanding how transfers from the federal government correlate with their revenue sources (see Knight (2002)). Motor fuel taxes are another interesting addition, because of their role in providing funds from transportation. The choice of whether to do an ad valorem tax or per gallon tax shifts some of the risks from motor fuel prices between individuals and state governments. Anderson and Thompson (2014) provide an in-depth analysis of the optimal mix of ad valorem and per gallon taxes to fund highways within a state. Table A.10 reports estimates of a decomposition of motor fuel tax revenue to demonstrate how the analysis in this paper could be extended to these other revenue sources. Panel A reports that the tax (cents per gallon) on motor fuel has increased from an average of 16.55 before 2000 to 20.14 after 2000. Between these two periods, however, volatility has only increased slightly from 18.24 to 18.70. The decomposition estimates in Panel B suggest that changes in tax rates and economic conditions both explain roughly half of the small increase in volatility.

Appendix B.5 Volatility Experienced by the Average Person

An observation in the preceding analyses has been a state-year. All estimates therefore are the average state's experience. Another equally valid way of doing the analysis is to weight each state-year observation by population. The estimates weighted by population provide the average person's experience with tax revenue volatility. Table 7 reports these estimates. These estimates are generally similar and show that changes in tax rates contributed more to the increased volatility experienced by the average person than the average state for the income and corporate tax revenues and slightly less for sales tax revenues. For example, when the data is weighted by population, 87% of the increase in income tax revenue volatility can be explained by changes in tax rates, which is larger than the baseline estimate of 67%.