TAX BURDEN AND THE MISMEASUREMENT OF STATE TAX POLICY

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Abstract

Tax Burden, defined as the ratio of total tax revenues over personal income, is prominently used to summarize state tax policy. We analyze the empirical relationship between changes in Tax Burden and changes in state tax policy from 1987 to 2000 – as measured by states' own forecasts of the revenue impacts of tax legislation – and find that Tax Burden contains substantial measurement error. We explain this result by decomposing Tax Burden changes into three components: (1) changes in state tax policy, (2) income-induced changes in revenue that are unrelated to state tax policy, and (3) other factors that do not measure state tax policy. We empirically demonstrate the statistical significance of the second component, highlighting important consequences for studies that estimate the impact of taxes on economic growth.

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I. INTRODUCTION

There is a great interest in understanding the effect of taxes on economic growth. In analyzing tax policy, both policy makers and researchers often rely on simplistic measures to summarize diverse and complex tax systems. The international growth literature, for example, typically represents a country's taxes with the variable "Average Tax Rate," defined as the ratio of total tax receipts to gross domestic product. Spanning more than 30 years, prominent research using this measure includes Goode (1968), Musgrave (1969), Koester and Kormendi (1989), Bizer and Durlauf (1990), Engen and Skinner (1992), Easterly and Rebelo (1993), Karras (1999), Padovano and Galli (2001), and Garibaldi and Mauro (2002).[1] The analogue in the state and local economic development literature is "Tax Burden," defined as the ratio of state and local tax revenues to personal income.[2]

Tax Burden, like Average Tax rate, is known to suffer from a number of deficiencies (Nelson, 2000; Wasylenko, 1997; Gold, 1996; Quan and Beck, 1987; Benson and Johnson, 1986).[3] Accounting for statutory differences in tax policy across states, however, is an enormous task with seemingly insurmountable empirical problems.[4] It is no wonder that Tax Burden and its variants continue to play prominent roles in empirical studies, including Dye (1980), Helms (1985), Benson and Johnson (1986), Canto and Webb (1987), Mofidi and Stone (1990), Yu, Wallace, and Nardinelli (1991), Fisher and Navin (1992), Mullen and Williams (1994), Carroll

[1] See Padovano and Galli (2001) and Koester and Kormendi (1989), and Slemrod (1995) for reviews of the international growth literature that uses average tax rate.
[2] Surveys of this literature may be found in Bartik (1991) and Wasylenko (1997).
[3] Although the literature recognizes the economic distinction between marginal and average tax rates, making the empirical distinction is problematic (Koester and Kormendi, 1989; Mullen and Williams, 1994) In some instances, the average tax rate is offered as a proxy for the marginal (Padovano and Galli, 2001).
[4] Benson and Johnson (1986, p. 392, FN 7) comment that such an attempt would be "frothing" with errors. Nelson (2000) provides an example of a conscientious attempt to use changes in statutory rates to measure state tax policy. However, he acknowledges that "tax legislation pertaining to the definition of a tax base … and tax credits are not considered" (page 542f.) Further, he is only able to characterize tax rate changes within – but not across – revenue categories (e.g., individual income tax, corporate income tax, sales tax, etc.) "with no distinction given to the magnitude of the rate change" (page 543). Where states raised income tax rates for some tax brackets and lowered rates for other brackets, the observation was omitted (page 558).

and Wasylenko (1994), Knight (2000), Caplan (2001), and Yamarik (2000, 2004). This also explains why state Tax Burdens are closely monitored by prominent U.S. organizations, including the Tax Foundation, the National Tax Association, the Federation of Tax Administrators, and the Pew Center on the States.

Despite acknowledged shortcomings, little is known about the reliability of Tax Burden as a measure of state tax policy. Our study is the first quantitative analysis of this issue. We analyze state-generated forecasts of revenue impacts associated with new tax legislation. If Tax Burden is a reliable indicator of changes in state tax policy, then changes in Tax Burden should generally correspond to the changes predicted by the state-generated revenue forecasts. We find that it does not.

We explain the source of the measurement error by decomposing Tax Burden changes into three components: (1) changes in state tax policy, (2) income-induced changes in revenue that do not measure state tax policy, and (3) other factors that do not measure state tax policy. To the extent that they matter, the last two components cause Tax Burden to mismeasure state tax policy. We empirically demonstrate the statistical significance of the income-induced changes in revenue.

Our results are of the good news/bad news variety. The good news is that changes in Tax Burden are positively and significantly related to changes in state tax policy. The bad news is that Tax Burden contains a substantial degree of measurement error. This finding is important for two reasons. First, it sheds doubt on the validity of previous research that has used the flawed measure, Tax Burden, to represent states' tax policies (and, by implication, cross-country research that has used Average Tax Rate). Second, it highlights the need for improved measures of taxes and policy impacts. The conclusion presents guidance for future research.

II. DIRECT MEASURES OF STATE TAX POLICY

State laws generally require states to estimate the budgetary impacts of tax and spending legislation. This information is collected by two national organizations -- the National Association of State Budget Officers (NASBO) and the National Conference of State Legislatures (NCSL). NASBO is an independent professional organization for the chief financial advisors to governors, including heads of state budget offices, state finance departments and their staffs. NCSL is a bipartisan organization that serves state legislatures and represents their interest to federal policy makers. Both organizations began conducting annual surveys of their membership regarding state tax policy in 1987.

NASBO, in conjunction with the National Governors' Association, surveys state budget officers.[5] Among other things, respondents provide estimates of changes in the next fiscal year's tax revenues resulting from changes in tax legislation. NCSL surveys state legislative staff.[6] Historically, the NCSL has used two methods to report tax change impacts. The baseline method (NCSL-B), available as an annual time series from 1987 to 1997, tracks tax legislation changes adopted in a given year in terms of the impact on the following fiscal year. It was discontinued in favor of the taxpayer liability method (NCSL-TL), which was initiated in 1995. The NCSL-TL series provides estimates of changes in the taxes actually paid by taxpayers.[7]

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[5] NASBO estimates are reported in a series entitled *The Fiscal Survey of the States* (1987-2002). The latest estimates are available online at www.nasbo.org.

[6] NCSL estimates are published in *State Budget Actions* (1987-1989), *State Budget and Tax Actions* (1990-1991) and *State Tax Actions* (1992-2002).

[7] For example, in the tax liability method, multi-year tax changes are credited to the fiscal year when the change is scheduled to take effect. Thus, if tax increases are phased in over a three-year period, the tax liability method shows three years of increases, whereas the baseline method only shows changes in the first year. Further, if the legislature decides to extend a tax increase that was previously scheduled to expire, or to postpone a tax decrease that was previously scheduled to take effect, the tax liability method shows no change in taxes, while the baseline measure would show an increase. See *State Tax Actions* 1996 for a comparison of the treatment of tax changes under both methods.

In addition to definitional variations on the nature and timing of tax changes, the NASBO and NCSL surveys also differ with respect to when information is collected. Thus, revisions in revenue forecasts may be picked up by one survey and not by another. FIGURE 1 compares the NASBO and NCSL-collected, state revenue forecasts associated with tax policy changes. In the figure, fiscal year represents the year that the tax changes are legislated to take effect. Despite some differences, the overall impression from FIGURE 1 is that the different series present similar pictures of revenue changes resulting from changes in states' tax policies.[8]

We take as our point of departure that the state revenue forecasts collected by NASBO and NCSL represent unbiased estimates of the revenue impacts of changes in state tax policy. Corroborating support for employing this assumption comes from three sources: (i) previous research on strategic bias in state revenue forecasts, (ii) personal conversations with professional staff at NASBO, NCSL, and state budgetary offices, and (iii) the use of these series in recent studies.

While no studies directly evaluate the accuracy of state revenue forecasts associated with tax legislation, some studies have investigated state forecasts of *total* tax revenues—a related subject.[9] No conclusive evidence of bias has been found.[10] However, even if states strategically bias total revenue forecasts, it does not follow that this bias would extend to revenue forecasts of specific tax legislation. These latter forecasts are likely to be more closely scrutinized than

[8] See Merriman (2000) for further discussions of the NASBO and NCSL estimates.

[9] Various hypotheses address why policymakers might want to either over- or under-state expected revenues (Klay, 1983; Rodgers and Joyce, 1996). These include partisan politics and aversion to revenue shortfalls. In contrast, other researchers argue that the overriding concern of the revenue forecast process is to minimize the costs associated with inaccurate forecasts (Mocan and Azad, 1996; Shkurti and Winefordner, 1989; Bretschneider et al., 1989). Budget shortfalls cause cuts in program spending while surpluses can be seen as evidence of excessive tax rates or the underfunding of public goods (Feenberg et al., 1989).

[10] Building on Cassidy et al. (1989), Bretschneider and Gorr (1992) find that a complicated mix of partisan politics and fiscal stress factors drive forecast errors in sales tax revenues. In contrast, Mocan and Azad (1995) find no systematic bias in general fund revenues and little evidence of political and institutional influences as a whole. This is perhaps the most econometrically rigorous analysis of state revenue forecast errors. It uses a rich set of forecast variables, including the source of state and federal economic trend forecasts for 20 states from 1986-92, to estimate a cross section, times series model with random effects.

overall budget forecasts since they are inputs in the legislative process and impact specific economic groups. As such, they need to be credible to many different constituencies.[11] Personal conversations with current and former professionals from NASBO, NCSL, and several state budgetary offices provided anecdotal confirmation that the survey responses supplied by the states are untainted by strategic bias.

Finally, we note that several recent studies have employed the NASBO and NCSL-collected revenue forecasts as direct measures of state tax policy. Poterba (1994) and Poterba and Rueben (2001) use NASBO data to represent state fiscal policy in their studies of how states respond to unexpected revenue shocks. Merriman (2001) uses both series in his analysis predicting changes in tax legislation. Maag and Merriman (2003) use NASBO-related estimates to investigate tax policy responses to the 1990 and 2001 recessions.

III. QUALITATIVE EVIDENCE THAT TAX BURDEN MISMEASURES STATE TAX POLICY

We define the variable *Tax Burden* as the ratio of state (but not local) tax revenues (R) over Personal Income (Y),

(1) $\quad Tax\ Burden_{st} = R_{st}/Y_{s,t-1}.$

We exclude local tax revenues in order to be consistent with the NASBO and NCSL-collected estimates. Note also that tax revenues are reported by fiscal year, while state Personal Income is measured over the calendar year. Following convention, Personal Income is from the calendar year that spans the beginning of the fiscal year.[12]

[11] Corroborating this interpretation are the similarities in the NASBO and NCSL estimates (cf. FIGURE I), despite originating from organizations facing different political pressures.

[12] For example *Tax Burden* for 1996 would have tax revenues corresponding to Fiscal Year 1996 (which typically runs from July 1, 1995 through June 30, 1996) divided by Personal Income for calendar year 1995.

FIGURE 2 compares the *Tax Burden* time series with the NASBO and NCSL-B time series for the state of Iowa for fiscal years 1988-2001.[13] For the most part, Iowa's *Tax Burden* series behaves in the manner expected of a reliable measure of state tax policy: it rises during years in which tax legislation was projected to increase state revenues, declines during years in which tax legislation was projected to decrease state revenues, and stays the same when no changes in state tax policy occurred.

A careful examination of the *Tax Burden* series for all the states, however, reveals that Iowa's experience is the exception, not the rule. FIGURES 3 and 4 illustrate two typical scenarios in which *Tax Burden* mismeasures state tax policy. In FIGURE 3, large increases in Louisiana's taxes in 1989 had little effect on the state's *Tax Burden*. Furthermore, during the early 1990's, legislated tax increases corresponded with a general decline in the *Tax Burden* series. In contrast, the example in FIGURE 4 shows large movements in Michigan's *Tax Burden* from 1988 through 1994 despite little change in that state's tax policy. Cases like Louisiana where significant changes in state tax policy correspond with little, or even perverse, movement in *Tax Burden;* and Michigan, where large movements in *Tax Burden* are not generated by changes in tax legislation, are common. In fact, the motivation for this study came from an (unsuccessful) attempt in previous research to identify significant tax legislation from movements in states' *Tax Burden* time series.[14]

FIGURE 5 aggregates data from all the states to present an overall picture of how well changes in *Tax Burden* correspond to changes in state tax policy.[15] According to both the

[13] The NCSL-TL series is omitted because it is available for only a small number of years. However, as discussed above, it bears close resemblance to the NASBO series. The series only extend to 2001 because this is the most recent year for which *Tax Burden* could be calculated.

[14] Figures representing *Tax Burden* time series for each state may be accessed via the internet at: "http://faculty-staff.ou.edu/R/Cynthia.Rogers-1/TAX/TAXBURDEN.htm".

[15] In FIGURE 5, *Tax Burden* for the U.S. is calculated as the ratio of the sum of state tax revenues for the U.S. over national Personal Income.

NASBO and NCSL-B measures, states raised taxes on net every year between 1988 and 1994. Yet, the value of *Tax Burden* in 1994 was about the same as it was in 1988. States lowered taxes on net every year from 1996 to 2001. Except for fiscal year 2001, however, there is little evidence of these tax cuts in the corresponding *Tax Burden* series. Clearly, *Tax Burden* does not rise (fall) during those years when states were increasing (decreasing) taxes as one would expect a reliable tax policy measure to do.

The previous graphical analysis presents compelling qualitative evidence that changes in *Tax Burden* do not reliably reflect whether states are increasing or decreasing their taxes. It raises important questions about the severity and implications of the mismeasurement of tax policy for investigations affected by it. Accordingly, the remainder of this study offers the first attempt to quantify the extent to which *Tax Burden* mismeasures state tax policy, and the consequent effects for estimates of taxes on economic growth.

IV. EVALUATING THE SOURCES OF TAX BURDEN MEASUREMENT ERROR

A. The Decomposition of Tax Burden

To investigate the implications of measurement error, we develop a theoretical structure relating the *Tax Burden* variable to actual state tax policy. Following the literature, the relationship between a state's tax revenues (R) and its income (Y) is approximated with a linear revenue function[16]:

$$(2) \qquad R_{st} = \beta_{0,st} + \beta_{1,st} Y_{s,t-1} + \varepsilon^{R}_{st},$$

[16] See for example Koester and Kormendi (1989) and Mullen and Williams (1994).

where ε_{st}^{R} is a mean-zero error term assumed to be uncorrelated with state income. Thus, tax policy for state *s* at time *t* can be characterized by the pair $(\beta_{0,st}, \beta_{1,st})$, where $\beta_{1,st}$ is the state's effective marginal tax rate on income at time *t*.

A "true" measure of the revenue change caused by a change in state tax policy parameters $(\beta_{0,st}, \beta_{1,st})$ in fiscal year *t*, which shows up in fiscal year *t+1* revenues, should hold income constant. This can be specified as follows,

$$(3) \qquad \Delta Taxes_{st}^{True} = \Delta Taxes_{st} \mid_{Y} = \Delta\beta_{0,st} + \Delta\beta_{1,st} \cdot Y_{s,t-1},$$

where $\Delta\beta_{0,st}$ is the component of tax changes that does not change with a state's income, and $(\Delta\beta_{1,st} \cdot Y_{s,t-1})$ is the component of tax changes that are affected by a state's income.

Let us consider measuring the change in state tax policy by the change in *Tax Burden,*

$$(4) \qquad \Delta TaxBurden_{st} = Tax\ Burden_{s,t+1} - Tax\ Burden_{st} = \frac{R_{s,t+1}}{Y_{st}} - \frac{R_{st}}{Y_{s,t-1}}.$$

Substituting Equation (2) into Equation (4), the relationship can be expressed as,

$$(5) \qquad \Delta TaxBurden_{st} = \Delta\beta_{1,st} + \left(\frac{\beta_{0,st+1}}{Y_{st}} - \frac{\beta_{0,st}}{Y_{s,t-1}}\right) + \left(\frac{\varepsilon_{s,t+1}^{R}}{Y_{st}} - \frac{\varepsilon_{st}^{R}}{Y_{s,t-1}}\right).$$

Equation (5) makes clear that changes in state income ($Y_{s,t-1}$) cause changes in *Tax Burden* even when there is no corresponding change in state tax policy parameters $(\beta_{0,st}, \beta_{1,st})$. As we shall subsequently demonstrate, this is not the only problem associated with using *Tax Burden* to measure the impact of changes in tax policy.

Substituting Equation (3) into (5) yields the following:

$$(6) \qquad \Delta TaxBurden_{st} = \frac{\Delta Taxes_{st}^{True}}{Y_{s,t-1}} + \beta_{0,st+1}\left(\frac{Y_{s,t-1} - Y_{st}}{Y_{s,t-1}Y_{st}}\right) + \eta_{st},$$

where $\eta_{st} = \left(\frac{\varepsilon^{R}_{s,t+1}}{Y_{st}} - \frac{\varepsilon^{R}_{st}}{Y_{s,t-1}} \right)$, $E(\eta_{st}) = 0$, and η_{st} is heteroscedastic. Note that the coefficient on $\frac{\Delta Taxes^{True}_{st}}{Y_{s,t-1}}$, the variable measuring the true change in state tax policy, is one.

Equation (6) decomposes the change in *Tax Burden* into three components. The first term is the change in *Tax Burden* due to the change in state tax policy. The second term represents the change in *Tax Burden* due to changes in income. The third term is composed of miscellaneous factors that are unrelated to state tax policy. The latter two terms cause *Tax Burden* to mismeasure state tax policy. Estimation of Equation (6) would provide an indication of the extent of this measurement error. Unfortunately the policy variable $\Delta Taxes^{True}_{st}$ is unobserved. In the remainder of this section, we devise a strategy for overcoming this problem, allowing us to estimate the components of the *Tax Burden* variable.

B. A Consistent Estimator of Tax Policy Based on State Revenue Forecasts

This section shows how the unobserved policy variable, $\Delta Taxes^{True}_{st}$, can be expressed as a function of observed variables. Let the variable $\Delta Taxes^{Forecast}_{st}$ represent the NASBO/NCSL-collected forecasts of the revenue change at time *t+1* attributed to a tax policy change at time *t*. In the context of the model above,

(7) $$\Delta Taxes^{Forecast}_{st} = \Delta\beta_{0,st} + \left(\Delta\beta_{1,st} \cdot Y^{F}_{st}\right),$$

where $\Delta\beta_{0,st}$ is the component of tax changes that does not change with a state's income[17], Y_{st}^{F} is the forecasted value of state income for the next year, and $\left(\Delta\beta_{1,st} \cdot Y_{st}^{F}\right)$ is the component of tax changes that are affected by a state's income.[18]

We need to make two assumptions in order to express $\Delta Taxes_{st}^{True}$ as a function of observables. First, we assume that $\Delta\beta_{0,st} = 0$. In this case, it follows from Equations (3) and (7) that

$$(8) \qquad \frac{\Delta Taxes_{st}^{True}}{Y_{s,t-1}} = \frac{\Delta Taxes_{st}^{Forecast}}{Y_{st}^{F}}.$$

Note that previous studies estimating marginal tax rates assume both (i) $\Delta\beta_{0,st} = 0$ and (ii) $\Delta\beta_{1,st} = 0$; i.e., they assume a linear revenue function that does not vary over time (e.g., Koester and Kormendi, 1989; Becsi, 1996). In comparison, our approach is less restrictive. However, there is an additional reason to support the assumption that $\Delta\beta_{0,st} = 0$: As a practical matter, the effect of this assumption is small. The Appendix demonstrates that under reasonable assumptions, the error associated with measuring $\Delta Taxes_{st}^{True}$ using states' forecasts of tax policy changes when $\Delta\beta_{0,st} \neq 0$ will generally be less than 5%.

The second assumption we make is that the relationship between the realized and forecasted values of state income is given by

$$(9) \qquad Y_{st} = \left(1 + \varepsilon_{st}^{F}\right) Y_{st}^{F},$$

where ε_{st}^{F} represents the percentage difference between the income forecast developed by state budgeters and the realized value of state income, and $E\left(\varepsilon_{st}^{F}\right) = 0$.[19]

[17] Note that the NASBO/NCSL-collected forecasts consist solely of taxes, excluding fees.

[18] $\Delta Taxes_{st}^{Forecast}$ is the same variable that Poterba (1994) calls "$\Delta TAXNEXT_{st}$."

Substituting Equation (9) into Equation (8) produces the following relationship,

$$(10) \qquad \frac{\Delta Taxes_{st}^{Forecast}}{Y_{st}} = \frac{\Delta Taxes_{st}^{True}}{Y_{s,t-1}} + \upsilon_{st},$$

where $\upsilon_{st} = -\frac{\Delta Taxes_{st}^{Forecast}}{Y_{st}} \cdot \varepsilon_{st}^{F}$, υ_{st} is heteroscedastic, and $\underset{T\to\infty}{plim}\left(\sum_{t=1}^{T}\frac{\upsilon_{st}}{T}\right) = 0$. Thus, the ratio of the observed variables $\Delta Taxes_{st}^{Forecast}$ and Y_{st} is a consistent estimate of the change in state tax policy in the sense that $\sum_{t=1}^{T}\frac{\Delta Taxes_{st}^{Forecast}}{Y_{st}}\Big/T$ is arbitrarily close to $\sum_{t=1}^{T}\frac{\Delta Taxes_{st}^{True}}{Y_{s,t-1}}\Big/T$ for sufficiently large *T*.

Although $\frac{\Delta Taxes_{st}^{Forecast}}{Y_{st}}$ and $\Delta TaxBurden_{st}$ both suffer from measurement error, the nature of the errors are different. The measurement error in the former stems from errors in forecasting next year's state income (ε_{st}^{F}). In contrast, the measurement error in $\Delta TaxBurden_{st}$ is due to changes in income as well as miscellaneous factors that are unrelated to state tax policy. These measurement errors have different consequences to the extent that these other sources of measurement error matter.

C. Quantitative Estimation of Mismeasurement in the *Tax Burden* Variable

Having shown that the observed variable $\frac{\Delta Taxes_{st}^{Forecast}}{Y_{st}}$ is a consistent estimator of the unobserved variable $\frac{\Delta Taxes_{st}^{True}}{Y_{s,t-1}}$, we employ the former as a proxy in Equation (6), yielding the following estimable regression equation,

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[19] Note that the "next" year is Y_{st}, since the budget forecast is made at the beginning of fiscal year *t*, which begins in the calendar year corresponding to $Y_{s,t-1}$.

$$(11) \qquad \Delta Tax\ Burden_{st} = \alpha_0 + \alpha_1 \cdot \frac{\Delta Taxes_{st}^{Forecast}}{Y_{st}} + \alpha_{2,s}\left(\frac{Y_{s,t-1} - Y_{st}}{Y_{s,t-1}Y_{st}}\right) + \omega_{st},$$

where $\alpha_{2,s}$ is a state-specific coefficient estimating $\beta_{0,s}$.[20] The estimation is at best suggestive, since $\frac{\Delta Taxes_{st}^{Forecast}}{Y_{st}}$ measures $\frac{\Delta Taxes_{st}^{True}}{Y_{s,t-1}}$ with error (cf. Equation [10]).

Columns (1) and (2) of TABLE 1 report the results of estimating Equation (11) using the NASBO- and NCSL-collected, state revenue forecasts to calculate $\frac{\Delta Taxes_{st}^{Forecast}}{Y_{st}}$, respectively. Of particular interest are the 47 state-specific interaction terms (corresponding to the terms $\alpha_{2,s}\left(\frac{Y_{s,t-1} - Y_{st}}{Y_{s,t-1}Y_{st}}\right)$, *s=1,2,…47*, in Equation [11]). Due to space constraints, the individual coefficient estimates ($\hat{\alpha}_{2,s}$'s) are not reported. However, we note that all 47 coefficient estimates in each equation (NASBO and NCSL) are positive. More than two-thirds of them are individually significant at the 5 percent level. We shall reference this result below.

At the bottom of each of these columns we report the results of testing the null hypothesis that these coefficients are jointly equal to zero. In both cases, the hypothesis is soundly rejected (cf. "Hypothesis Test: State-Specific Interaction Terms"). The corresponding *p*-values are well below 0.1 percent. This provides statistical evidence that changes in state income induce significant movement in the *Tax Burden* variable, causing the *Tax Burden* variable to change even when there has been no change in state in tax policy (cf. Equation [5] and the subsequent discussion).

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[20] The reader may note that the error term in Equation (11) includes the components $\frac{\varepsilon_{s,t+1}^R}{Y_{st}}$ and $\frac{\varepsilon_{st}^R}{Y_{s,t-1}}$, where Y_{st} and $Y_{s,t-1}$ also appear as explanatory variables in the second term. However, recall that $E(\varepsilon_{st}^R) = 0$ and is assumed to be uncorrelated with the income variable.

TABLE 1 also yields insights about the other components of the change in *Tax Burden*. The component representing the change in *Tax Burden* due to actual changes in state tax policy, proxied in Equation (11) by $\frac{\Delta Taxes_{st}^{Forecast}}{Y_{st}}$, shows up as positive and significant in both Columns (1) and (2). Both of the estimated coefficients are less than *1* (0.5872 and 0.5578, respectively), as one would expect if $\frac{\Delta Taxes_{st}^{Forecast}}{Y_{st}}$ measured changes in state tax policy with error.

Finally, the component representing all of the other factors that cause *Tax Burden* to mismeasure tax policy is captured in Equation (11) by the regression error term, ω_{st}. This source of measurement error contributes to the corresponding low R^2 values of 0.209 and 0.273, respectively; though other factors, such as using an imperfect measure for $\frac{\Delta Taxes_{st}^{True}}{Y_{s,t-1}}$, also contribute.

So far our analysis provides evidence that changes in state income (income-induced movements along the revenue function) are a significant source of the measurement error in *Tax Burden*. The corresponding implications for empirical studies using *Tax Burden* to estimate the effects of taxes on economic growth are discussed in the next section.

V. AN ADDITIONAL SOURCE OF BIAS CAUSED BY INCOME-INDUCED MEASUREMENT ERROR IN THE *TAX BURDEN* VARIABLE

The preceding analysis demonstrates the substantial measurement error associated with using *Tax Burden* to measure state tax policy. As has been previously noted, measurement error that is uncorrelated with the dependent variable produces attenuation bias. If the measurement error is

correlated with the dependent variable, however, an additional bias is introduced that can swamp the effect of attenuation bias. The following provides an empirical demonstration.

Suppose we want to study the relationship between state economic growth and state tax policy. We define growth as the difference in the logs of annual, state Personal Income,

(12) $$Growth_{st} \equiv ln(Y_{st}) - ln(Y_{s,t-1}).$$[21]

FIGURE 6 shows the real time relationship between changes in state tax policy and state income. Changes in tax policy are made during fiscal year *t* and are effective beginning in fiscal year *t+1*. That means during their first year of being in force, tax changes coincide with the second half of calendar year *t* and the first half of calendar year *t+1*. Economic growth over calendar year *t* will be affected by changes in state tax policy made in fiscal year *t* (which overlap the second half of calendar year *t*) and changes in state tax policy made in fiscal year *t-1* (which overlap the first half of calendar year *t*).

Keeping in mind the relationship between fiscal years and calendar years, we develop the following model relating economic growth to taxes,

(13) $$\begin{aligned} Growth_{st} = {} & \gamma_0 + \gamma_1 ln(Y_{s,t-1}) + \gamma_2 \Delta Tax\ Policy_{st} + \gamma_3 \Delta Tax\ Policy_{s,t-1} \\ & + State\ Fixed\ Effects_{st} + Time\ Fixed\ Effects_{st} + error\ term_{st} \end{aligned}$$

where $s = 1,2,\ldots,S$, $t = 1,2,\ldots,T$, S and T represent the total number of states and time periods in our sample, and $\Delta Tax\ Policy_{st}$ is alternatively measured by (i) $\Delta Tax\ Burden_{st}$, (ii) $\frac{\Delta Taxes_{st}^{Forecast(NASBO)}}{Y_{st}}$, and (iii) $\frac{\Delta Taxes_{st}^{Forecast(NCSL)}}{Y_{st}}$, our three different measures of changes in state tax policy.

[21] *Growth* could alternatively be defined as the difference in the logs of annual, state Per Capita Personal Income. We use this alternative definition of growth below.

The first explanatory variable, $ln(Y_{s,t-1})$, represents initial income at the beginning of the calendar year and acknowledges the role that convergence plays in determining state economic growth. The next two variables, $\Delta Tax\ Policy_{st}$ and $\Delta Tax\ Policy_{s,t-1}$, capture the effects of state tax policy on economic growth, recognizing that calendar year *t* overlaps two fiscal years, and hence is affected by changes in tax policy made during fiscal years *t-1* and *t*. State and (calendar) year fixed effects are added to capture the influence of omitted factors that contribute to economic growth.

Obviously, this model omits many variables, such as physical and human capital investment and industrial composition, that economists have previously identified as being important determinants of regional growth. Its purpose is merely illustrative -- to demonstrate the importance of another source of measurement error bias in the *Tax Burden* variable.

We first demonstrate that estimated tax effects are affected by how one measures $\Delta Tax\ Policy$. As discussed above, three measures are available: $\Delta TaxBurden_{st}$ (cf. Equation [4]); and the two formulations of $\frac{\Delta TAXES_{st}^{Forecast}}{Y_{st}}$ (cf. Equation [8]), where $\Delta TAXES_{st}^{Forecast}$ is separately measured by the NASBO and NCSL-B revenue estimates, respectively.

Columns (1) and (2) of TABLE 2A report the results of estimating Equation (13) using data over the sample period 1987-2000. There are a total of 47 states for 13 years, resulting in 611 observations.[22] Since our focus is on the change in tax policy variables, we restrict our discussion to these coefficients for the sake of brevity.

Both the *Tax Burden* and NASBO-collected state forecasts show a negative relationship between increases in taxes and economic growth. In both cases, we convincingly reject the

[22] Note that we lose a year of observations due to using a lagged value for the $\Delta Tax\ Policy_{st}$ variable, since the NASBO data only go back to 1987.

hypothesis that changes in tax policy have no effect on economic growth (cf. "Hypothesis Tests: Tax Policy"). The resulting *F*-statistics for the test of $H_0 : \gamma_{\Delta Tax\ Policy_{st}} = \gamma_{\Delta Tax\ Policy_{s,t-1}} = 0$ are 4.975 and 4.873, respectively. Both values are significant below the 1 percent level. In these respects, the two measures of state tax policy give similar results.

They differ, however, in the implied timing of the tax effects. According to the *Tax Burden* specification, a one-percentage point increase in state tax rates adopted during fiscal year *t* -- which takes effect at the midpoint of calendar year *t* -- causes a 0.91 percent decrease in state Personal Income in calendar year *t*. In contrast, a one-percentage point increase in state tax rates adopted during fiscal year *t-1* causes a 0.13 percent decrease in state Personal Income in calendar year *t*. In other words, these results suggest that state tax policy has a relatively large immediate effect that quickly dissipates.

Contrast this with the results from the NASBO regression: A one-percentage point increase in state tax rates adopted during fiscal year *t* is associated with a decrease of 0.57 percent in economic growth in calendar year *t*. The same increase adopted during fiscal year *t-1* is estimated to decrease Personal Income growth by a larger 1.24 percent in year *t*. In other words, the NASBO-related estimates suggest that most of the economic effects of tax increases felt this calendar year come from tax changes made in the preceding fiscal year. While the absolute sizes of the effects will differ in subsequent regressions (along with some of the corresponding results from hypothesis tests), we shall see that this is a common pattern.

Consider next Columns (3) through (5) of TABLE 2A. These regressions utilize data from the sample period 1987-1997 to fit the restricted availability of the NCSL-B series. The estimates using *Tax Burden* show declines in economic growth during calendar year *t* of 1.35 and 0.61 percent associated with a one-percentage increase in tax rates adopted during fiscal years *t*

and *t-1*, respectively. The corresponding declines in economic growth estimated using the NASBO and NCSL series are 0.61 and 1.31 percent, and 0.29 and 0.98 percent, respectively. In other words, the NCSL data are similar to the NASBO data in showing a smaller immediate but longer-lasting effect of tax changes.[23]

TABLE 2B repeats the preceding analysis, except this time we look at the change in state Per Capital Personal Income (PCPI). While the tax effects are generally estimated to have a smaller impact on state PCPI growth, the same difference in the timing of the tax effects persists between the *Tax Burden* measure on the one hand, and the NASBO and NCSL estimates on the other.

We now demonstrate that this empirical result is likely an artifact associated with the composition of the *Tax Burden* variable. To demonstrate this, we substitute the three components of the change in *Tax Burden* from Equation (6) into Equation (13), to obtain

$$
\begin{aligned}
Growth_{st} = {} & \gamma_0 + \gamma_1 ln\left(Y_{s,t-1}\right) + \gamma_2 \left(\frac{\Delta Taxes_{st}^{True}}{Y_{s,t-1}} + \beta_{0,s} \left(\frac{Y_{s,t-1} - Y_{st}}{Y_{s,t-1} Y_{st}} \right) + \eta_{st} \right) \\
& + \gamma_3 \left(\frac{\Delta Taxes_{s,t-1}^{True}}{Y_{s,t-2}} + \beta_{0,s} \left(\frac{Y_{s,t-2} - Y_{s,t-1}}{Y_{s,t-2} Y_{s,t-1}} \right) + \eta_{s,t-1} \right) \\
& + State\ Fixed\ Effects_{st} + Time\ Fixed\ Effects_{st} + error\ term_{st}
\end{aligned}
\tag{14}
$$

Note that $Y_{s,t}$ appears both on the left hand side of the equation -- as part of the dependent variable, $Growth_{st} \equiv ln\left(Y_{st}\right) - ln\left(Y_{s,t-1}\right)$ -- and on the right hand side of the equation, in the variable $\Delta TaxBurden_{st}$ (i.e., the variable premultiplied by γ_2 -- cf. Equation [13]). As such, it represents a "redundant variable."[24]

[23] The overall size of the tax effects is estimated to be smaller using the NCSL data. Further, an *F*-test of the two tax policy variables fails to achieve significance at the 5 percent level.

[24] We don't have the same problem with $Y_{s,t-1}$ since it is included as a separate explanatory variable, $ln\left(Y_{s,t-1}\right)$, thus holding constant the effect of $Y_{s,t-1}$ in the two *Tax Burden* variables.

The bias that this introduces to the estimation of γ_2 depends on the sign of $\beta_{0,s}$. Recall from our earlier discussion of TABLE 1, we estimated positive signs for all 47, individual $\beta_{0,s}$ coefficients. Thus, an increase in Y_{st} would cause $Growth_{st}$ to increase while, at the same time, decreasing the size of $\Delta Tax\ Policy_{st}^{TaxBurden}$ via the second component. Ceteris paribus, this would induce a negative bias in the estimation of γ_2. This suggests that the estimate of a larger negative value for the coefficient of the *Tax Burden*-measure of $\Delta Tax\ Policy_{st}$ is likely the result of the way that *Tax Burden* is constructed. In other words, it does not represent a true "tax effect." This problem arises because the change in *Tax Burden* variable contains an income-related component that is unrelated to state tax policy, but correlated with economic growth.

The preceding empirical example is meant to illustrate how changes in *Tax Burden* that are unrelated to tax policy -- specifically, those changes caused by changes in income -- can bias estimated tax effects in a manner different from attenuation bias. Finally, note that decomposition of Equation (6) can guide researchers in model specification. For example, one could eliminate the bias in Equation (13) by specifying a model in which $Growth_{st}$ was a function of <u>lagged</u> values of changes in state tax policy, *a lá* a VAR model.

VI. CONCLUSION

This paper studies the degree to which *Tax Burden* distorts the measurement of state tax policy. We have some good news: The empirical evidence indicates that changes in *Tax Burden* are positively and significantly related to changes in state tax policy. Unfortunately, we also find evidence of substantial measurement error.

We decompose *Tax Burden* changes into three components: (1) changes in state tax policy, (2) income-induced changes in revenue that do not measure state tax policy, and (3) other

factors that do not measure state tax policy. The latter two categories constitute measurement error with respect to measuring state tax policy. Our empirical analysis establishes the quantitative and statistical importance of the second component. In other words, we demonstrate that changes in state income cause the *Tax Burden* variable to change even when there has been no change in state in tax policy.

In addition to standard attenuation bias due to measurement error, we also demonstrate the empirical importance of another kind of bias associated with income-induced measurement error. This latter bias occurs whenever the dependent variable is a function of income, because income also appears in the denominator of the *Tax Burden* variable. This has direct application to studies of economic growth: Income-induced movements in the *Tax Burden* variable that are unrelated to state tax policy will produce biased estimates of tax impacts. The combination of these two biases may explain why previous studies have estimated such a wide range of tax effects (Bartik, 1991; McGuire, 1992; Wasylenko, 1997).

These findings should be of particular interest to researchers interested in estimating the economic effects of taxes. On a positive note, this study demonstrates how state revenue forecasts can be used to construct consistent measures of state tax policy. We believe that researchers will find these forecast data increasingly attractive as the respective time series lengthen over time.

In the meantime, instrumental variables remain a potentially fruitful way to address measurement error bias in Tax Burden, and its cousin, Average Tax Rate. Statutory tax parameters (e.g., property and sales tax rates, income tax rate parameters as well as income bracket and tax credit data) are obvious candidates for instruments. In addition, researchers may find it useful to pursue alternative methodologies for measuring and estimating tax effects.

Representative agent models (e.g. Fisher and Peters, 1998) and new, quasi-experimental methods (e.g., Reed and Rogers, 2003; Reed and Rogers, 2004) are promising avenues for future research.

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TABLE 1
Estimating the Components of the *Tax Burden* Variable

VARIABLES	***Using NASBO estimates***	***Using NCSL estimates***
	(1)[a]	***(2)***[a]
Constant	0.0014 (4.86)	0.0015 (4.58)
$\frac{\Delta TAXES_{st}^{Forecast}}{Y_{st}}$	0.5872 (10.02)	0.5578 (8.19)
Other variables	State-Specific Interaction Terms[b]	State-Specific Interaction Terms[b]
Observations	658	517
R^2 **(Adjusted** R^2**)**	0.209 (0.146)	0.273 (0.198)
***Hypothesis Test*:** **State-Specific Interaction Terms**[c]	F = 2.211 (p-value = 0.000)	F = 2.356 (p-value = 0.000)

NOTES: *t*-statistics are reported in parentheses below the estimated coefficients. Hypothesis tests use White's heteroscedastic-consistent covariance matrix.

[a] The dependent variable is $\Delta Tax\ Burden_{st}$. Equation specification is that of Equation (11) in the text, with $\Delta TAXES_{st}^{Forecast}$ alternatively being measured by the NASBO- and NCSL-collected state revenue forecasts, respectively.

[b] 47 state-specific interaction terms, $\alpha_{2,s}\left(\frac{Y_{s,t-1}-Y_{st}}{Y_{s,t-1}Y_{st}}\right)$, are included in this equation.

[c] The associated null hypothesis is that the state-specific interaction terms are jointly equal to zero.

TABLE 2A
Estimating the Relationship Between Growth in State Personal Income and Different Measures of the Change in State Tax Policy[a]

	Sample Period: 1987-2000[b]		***Sample Period: 1987-1997[b]***		
VARIABLES	***Tax Burden[c]*** ***(1)***	***NASBO[c]*** ***(2)***	***Tax Burden[c]*** ***(3)***	***NASBO[c]*** ***(4)***	***NCSL[c]*** ***(5)***
Constant	0.9409 (4.17)	0.7999 (3.81)	1.3046 (3.94)	1.0730 (3.39)	1.1232 (3.45)
Initial Income	-0.0806 (-3.85)	-0.0674 (-3.46)	-0.1138 (-3.72)	-0.0923 (-3.15)	-0.0970 (-3.21)
$\Delta Tax\ Policy_{st}$	-0.9145 (-3.08)	-0.5677 (-1.57)	-1.3481 (-3.88)	-0.6108 (-1.59)	-0.2876 (-0.69)
$\Delta Tax\ Policy_{s,t-1}$	-0.1379 (-0.46)	-1.2431 (-2.67)	-0.6131 (-1.70)	-1.3117 (-2.62)	-0.9774 (-2.32)
Other variables	State + Year Fixed Effects	State + Year Fixed Effects	State + Year Fixed Effects	State + Year Fixed Effects	State + Year Fixed Effects
Observations	611	611	470	470	470
R^2 (Adjusted R^2)	0.512 (0.457)	0.510 (0.455)	0.519 (0.451)	0.502 (0.432)	0.494 (0.422)
***Hypothesis Tests*:**					
Tax Policy[d]	F = 4.975 (p-value = 0.007)	F = 4.873 (p-value = 0.008)	F = 7.572 (p-value = 0.001)	F = 4.430 (p-value = 0.012)	F = 2.741 (p-value = 0.066)
State Fixed Effects[e]	F = 11.489 (p-value = 0.000)	F = 11.306 (p-value = 0.000)	F = 8.064 (p-value = 0.000)	F = 8.509 (p-value = 0.000)	F = 7.950 (p-value = 0.000)
Year Fixed Effects[f]	F = 25.040 (p-value = 0.000)	F = 29.150 (p-value = 0.000)	F = 19.620 (p-value = 0.000)	F = 17.454 (p-value = 0.000)	F = 18.534 (p-value = 0.000)

<u>NOTES</u>: *t*-statistics are reported in parentheses below the estimated coefficients. Hypothesis tests use White's heteroscedastic-consistent covariance matrix.

[a] The dependent variable is $Growth_{st} = ln(Personal\ Income)_{st} - ln(Personal\ Income)_{s,t-1}$. Equation specification is that of Equation (13) in the text, with $\Delta Tax\ Policy_{st}$ alternatively measured by (i) $\Delta Tax\ Burden_{st}$, (ii) $\frac{\Delta Taxes_{st}^{Forecast(NASBO)}}{Y_{st}}$, and (iii) $\frac{\Delta Taxes_{st}^{Forecast(NCSL)}}{Y_{st}}$.

[b] The sample periods are limited by the availability of revenue forecasts. NASBO revenue forecasts are available for the years 1987-2000. NCSL revenue forecasts are available for the years 1987-1997.

[c] Columns (1) and (3) use the change in *Tax Burden* as the measure of state tax policy; Columns (2) and (4) use the NASBO revenue forecasts as their basis in calculating the change in state tax policy; and Column (5) uses the NCSL revenue forecasts.

[d] The associated null hypothesis is $\gamma_{\Delta Tax\ Policy_{st}} = \gamma_{\Delta Tax\ Policy_{s,t-1}} = 0$.

[e] The associated null hypothesis is that the state fixed effects are jointly equal to zero.

[f] The associated null hypothesis is that the year fixed effects are jointly equal to zero.

TABLE 2B
Estimating the Relationship Between Growth in State PCPI and Different Measures of Changes in State Tax Policy[a]

	Sample Period: 1987-2000[b]		***Sample Period: 1987-1997[b]***		
VARIABLES	***Tax Burden[c]***	***NASBO[c]***	***Tax Burden[c]***	***NASBO[c]***	***NCSL[c]***
	(1)	***(2)***	***(3)***	***(4)***	***(5)***
Constant	2.4789 (7.06)	2.4075 (7.02)	3.0417 (7.32)	2.9249 (7.03)	2.9413 (7.00)
Initial Income	-0.2547 (-6.86)	-0.2470 (-6.82)	-0.3137 (-7.14)	-0.3012 (-6.86)	-0.3030 (-6.82)
$\Delta Tax\ Policy_{st}$	-0.6658 (-2.52)	-0.4867 (-1.63)	-0.9295 (-2.98)	-0.4781 (-1.51)	-0.0404 (-0.11)
$\Delta Tax\ Policy_{s,t-1}$	0.0262 (0.09)	-0.7547 (-1.79)	-0.3378 (-1.03)	-0.7774 (-1.75)	-0.4020 (-1.12)
Other variables	State + Year Fixed Effects	State + Year Fixed Effects	State + Year Fixed Effects	State + Year Fixed Effects	State + Year Fixed Effects
Observations	611	611	470	470	470
R^2 (Adjusted R^2)	0.529 (0.477)	0.525 (0.473)	0.549 (0.485)	0.538 (0.472)	0.531 (0.465)
***Hypothesis Tests*:**					
Tax Policy[d]	F = 3.890 (p-value = 0.021)	F = 2.951 (p-value = 0.053)	F = 4.478 (p-value = 0.011)	F = 2.459 (p-value = 0.086)	F = 0.632 (p-value = 0.531)
State Fixed Effects[e]	F = 2.454 (p-value = 0.000)	F = 2.366 (p-value = 0.000)	F = 2.105 (p-value = 0.000)	F = 2.060 (p-value = 0.000)	F = 2.074 (p-value = 0.000)
Year Fixed Effects[f]	F = 44.020 (p-value = 0.000)	F = 46.112 (p-value = 0.000)	F = 38.677 (p-value = 0.000)	F = 31.704 (p-value = 0.000)	F = 33.489 (p-value = 0.000)

<u>NOTES</u>: *t*-statistics are reported in parentheses below the estimated coefficients. Hypothesis tests use White's heteroscedastic-consistent covariance matrix.

[a] The dependent variable is $Growth_{st} = ln(PCPI)_{st} - ln(PCPI)_{s,t-1}$. Equation specification is that of Equation (13) in the text, with $\Delta Tax\ Policy_{st}$ alternatively measured by (i) $\Delta Tax\ Burden_{st}$, (ii) $\frac{\Delta Taxes_{st}^{Forecast(NASBO)}}{Y_{st}}$, and (iii) $\frac{\Delta Taxes_{st}^{Forecast(NCSL)}}{Y_{st}}$.

[b] The sample periods are limited by the availability of revenue forecasts. NASBO revenue forecasts are available for the years 1987-2000. NCSL revenue forecasts are available for the years 1987-1997.

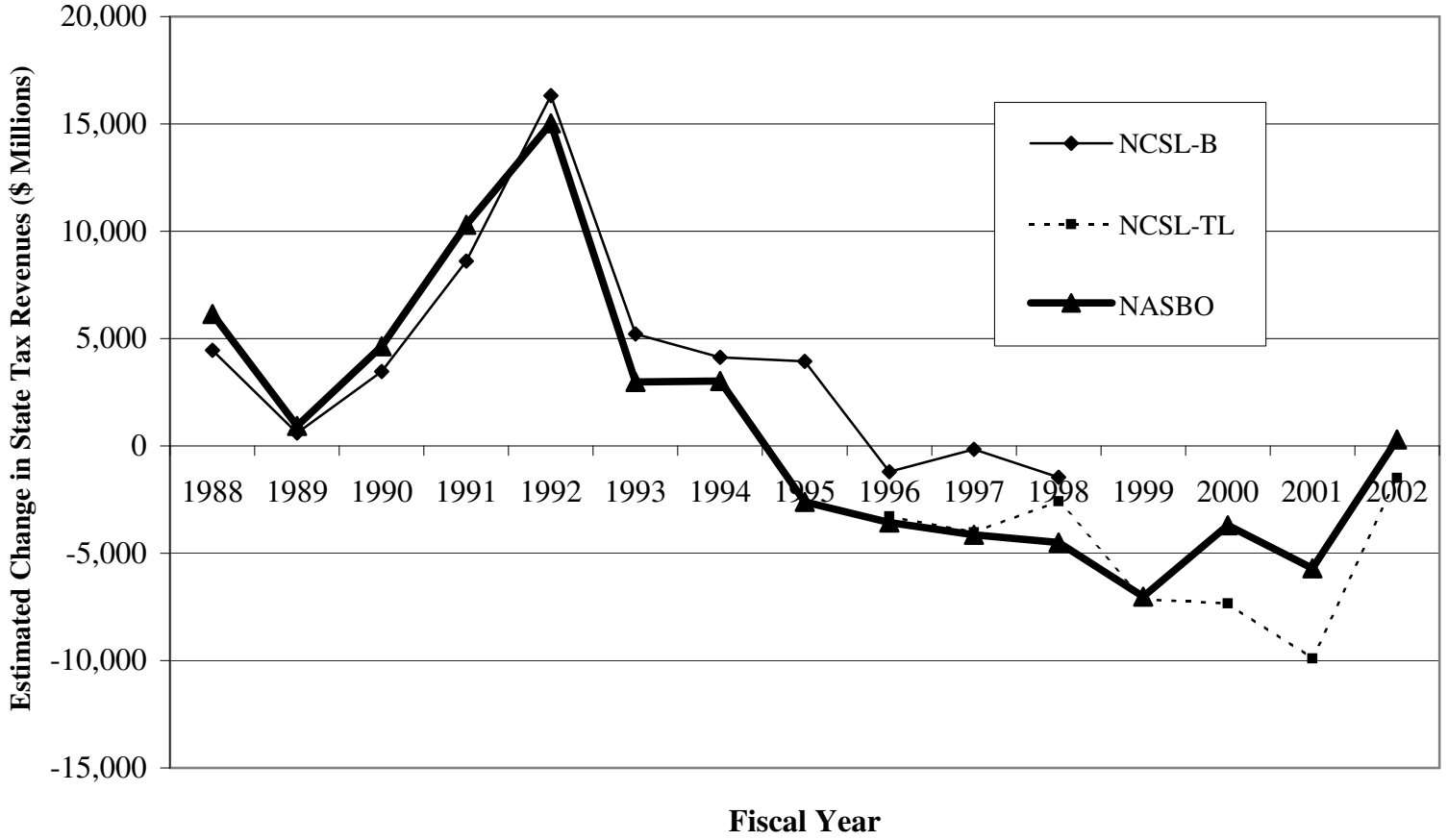
[c] Columns (1) and (3) use the change in *Tax Burden* as the measure of state tax policy; Columns (2) and (4) use the NASBO revenue forecasts as their basis in calculating the change in state tax policy; and Column (5) uses the NCSL revenue forecasts.

[d] The associated null hypothesis is $\gamma_{\Delta Tax\ Policy_{st}} = \gamma_{\Delta Tax\ Policy_{s,t-1}} = 0$.

[e] The associated null hypothesis is that the state fixed effects are jointly equal to zero.

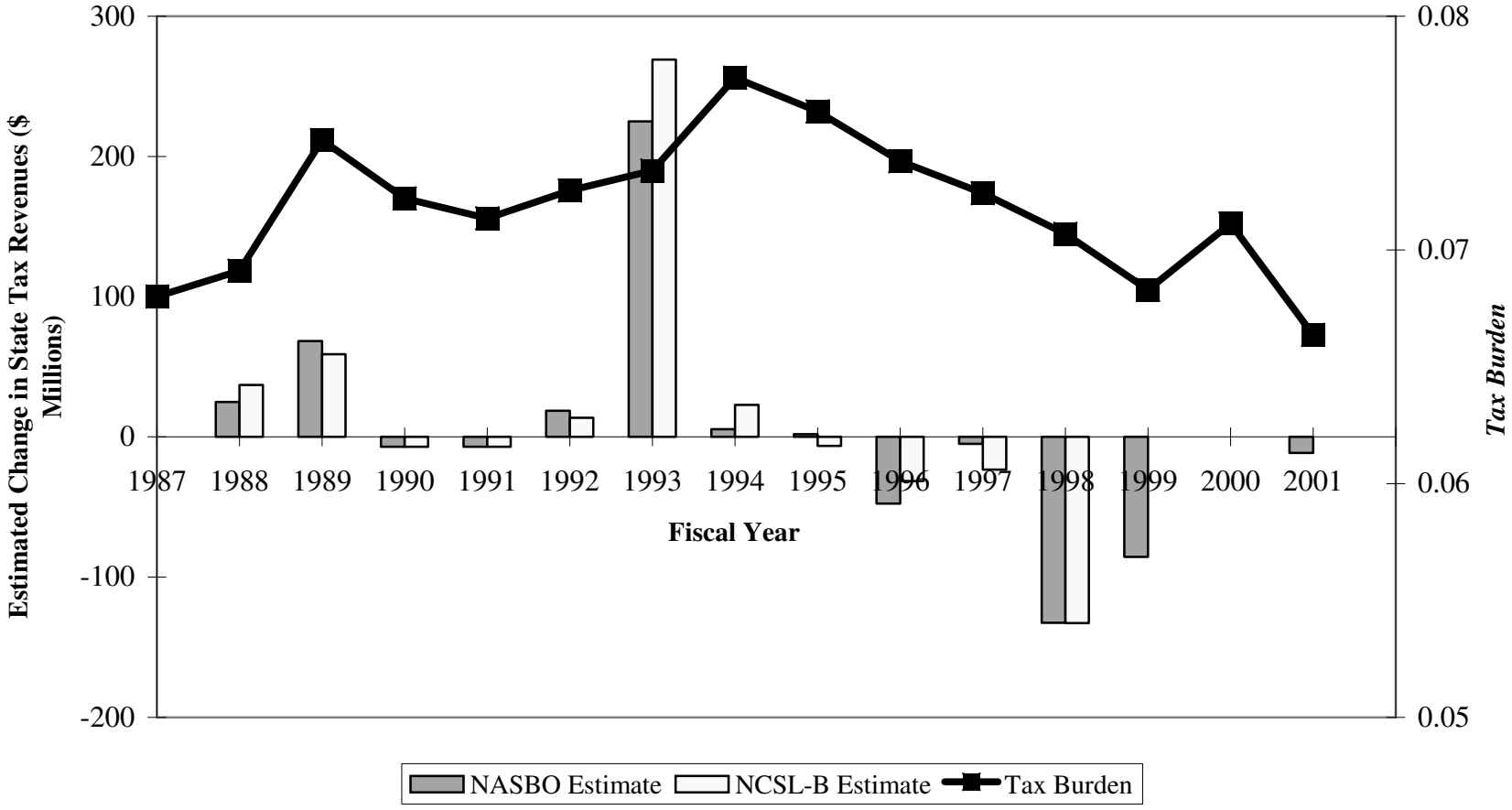
[f] The associated null hypothesis is that the year fixed effects are jointly equal to zero.

FIGURE 1
A Comparison of Three Measures of State Tax Policy Changes: NASBO, NCSL-B, and NCSL-TL



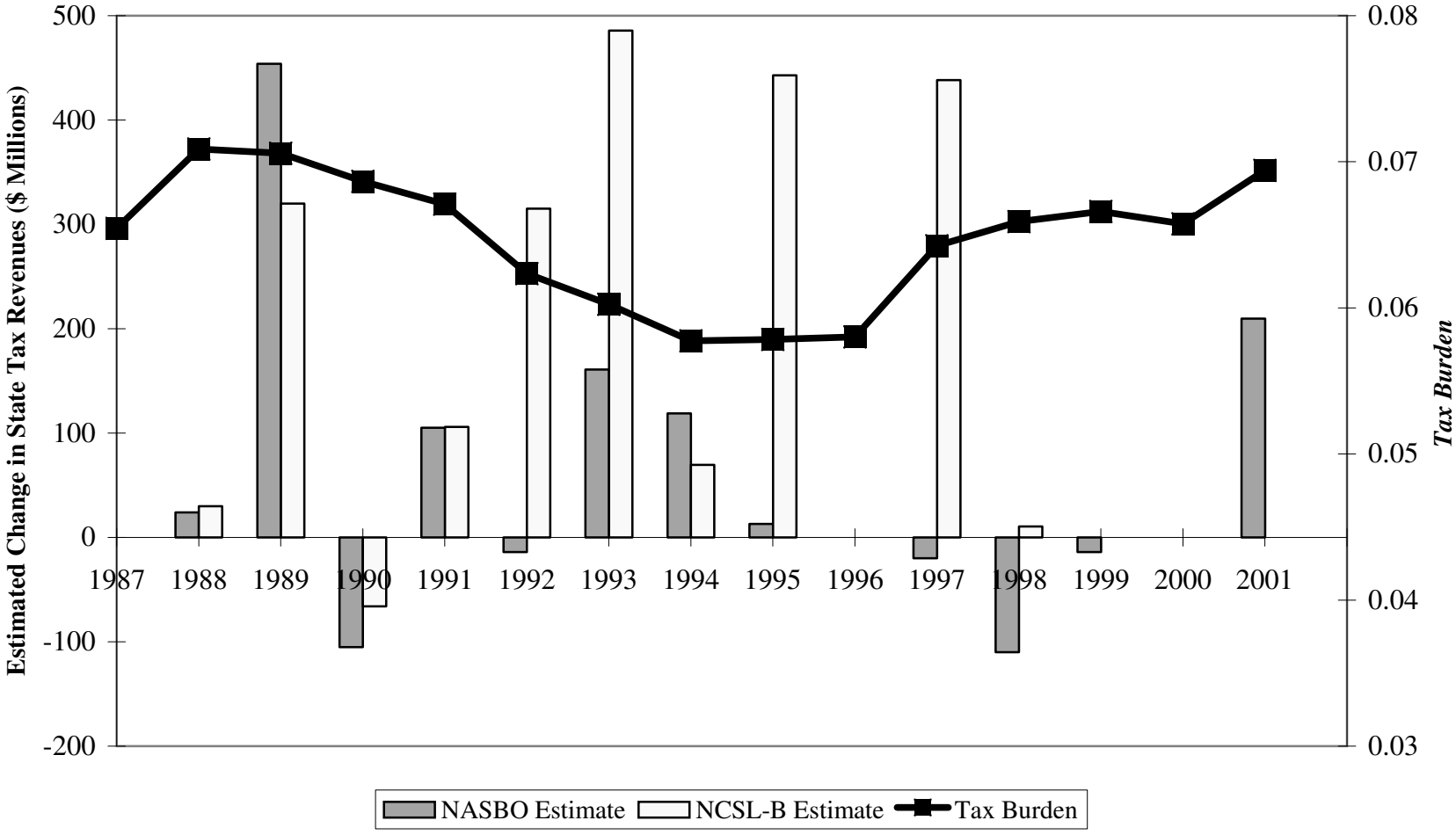
NOTES: The figure plots the annual sum of state tax changes as estimated by the NASBO, NCSL-B and NCSL-TL measures. NCSL-B and NCSL-TL refer to NCSL's "Baseline" and "Tax Liability" measures. The three measures are described in the text. Fiscal year refers to fiscal year when tax changes are estimated to take effect.

FIGURE 2
***Tax Burden* Versus Changes in State Tax Policy: Iowa**



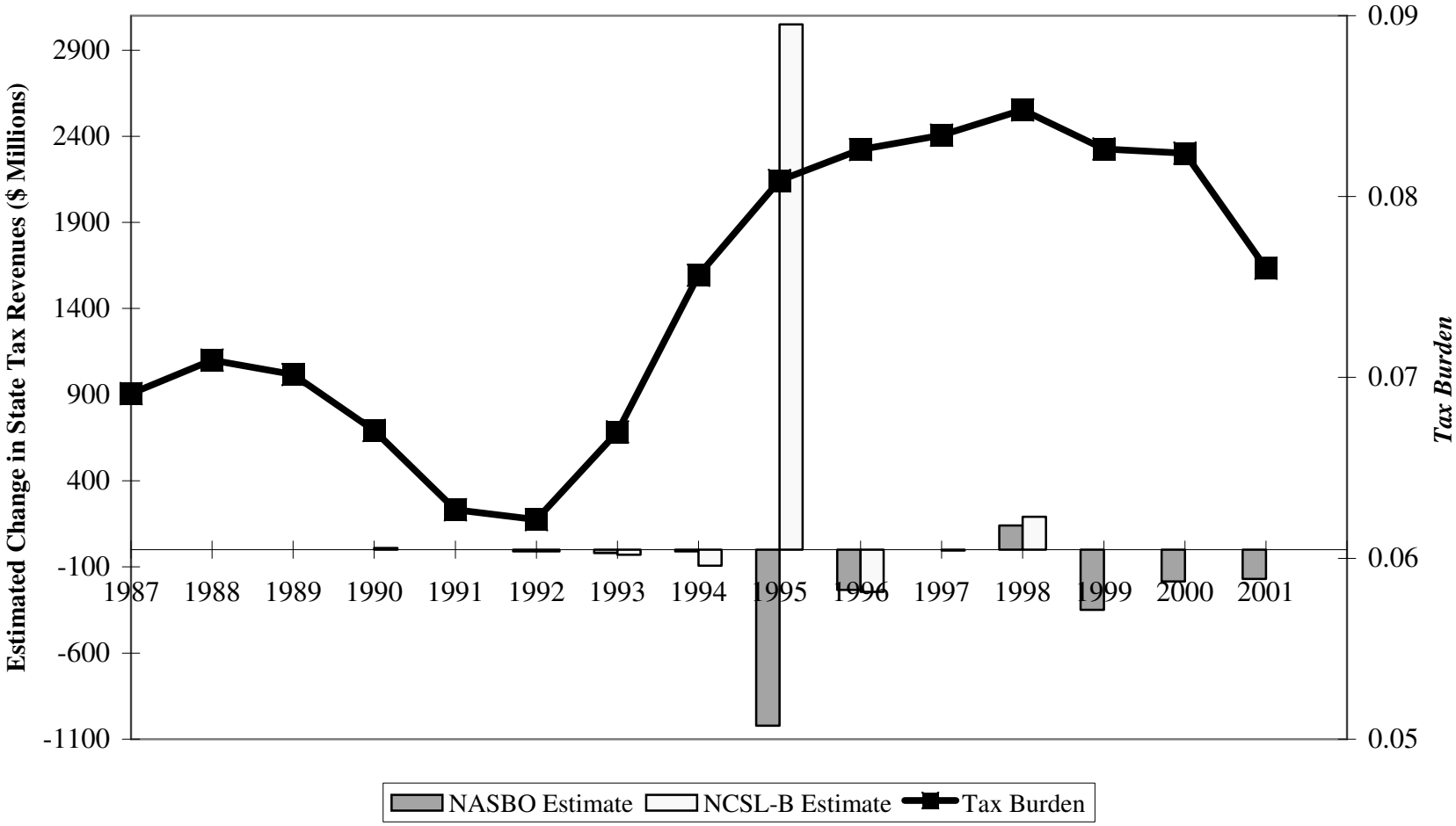
NOTES: The NASBO estimates run through 2002, while the NCSL-B estimates only extend through 1998. *Tax Burden* measures the ratio of total state tax revenues over total state Personal Income.

FIGURE 3
***Tax Burden* Versus Changes in State Tax Policy: Louisiana**



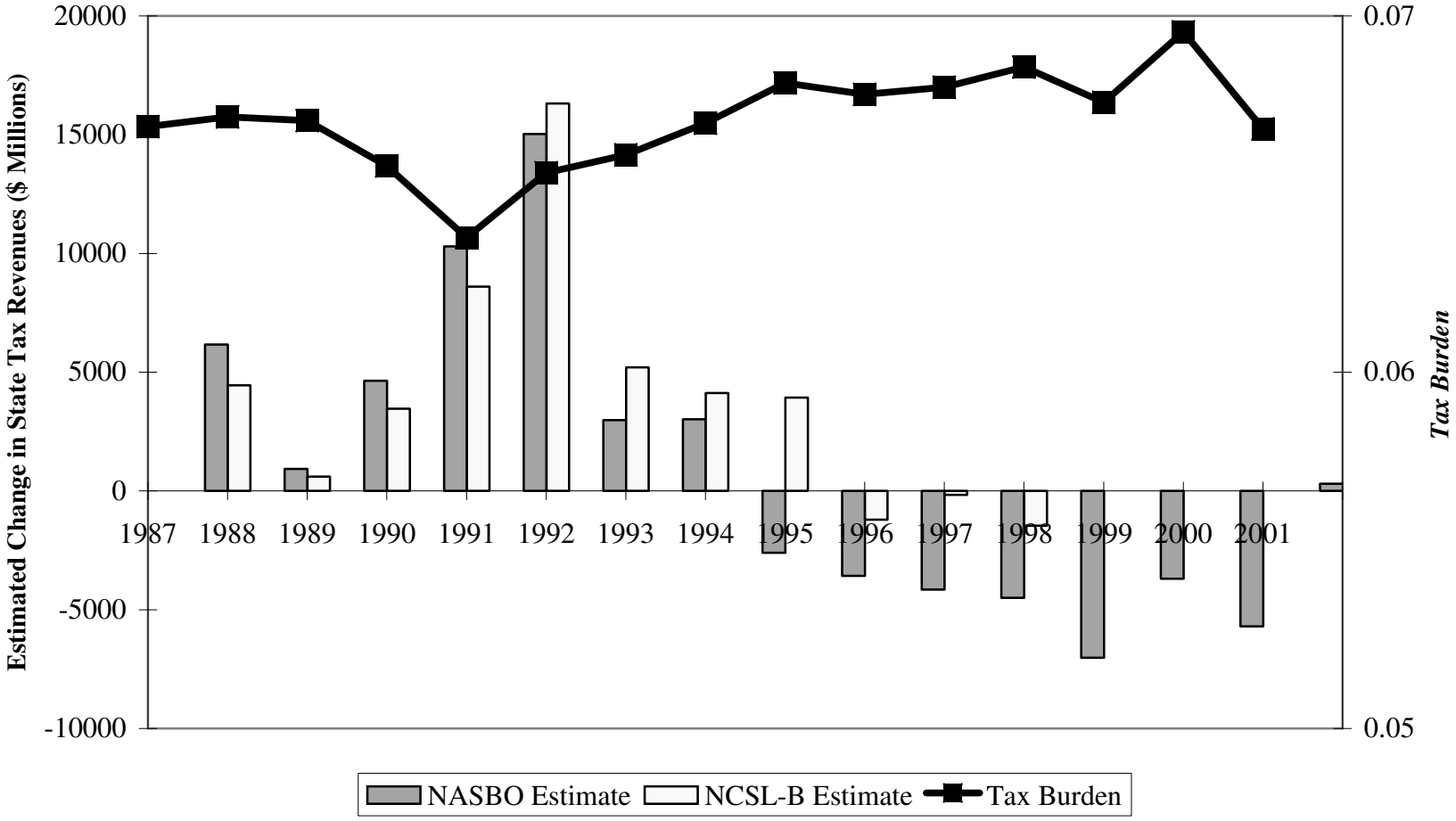
NOTES: The NASBO estimates run through 2002, while the NCSL-B estimates only extend through 1998. *Tax Burden* measures the ratio of total state tax revenues over total state Personal Income.

FIGURE 4
***Tax Burden* Versus Changes in State Tax Policy: Michigan**



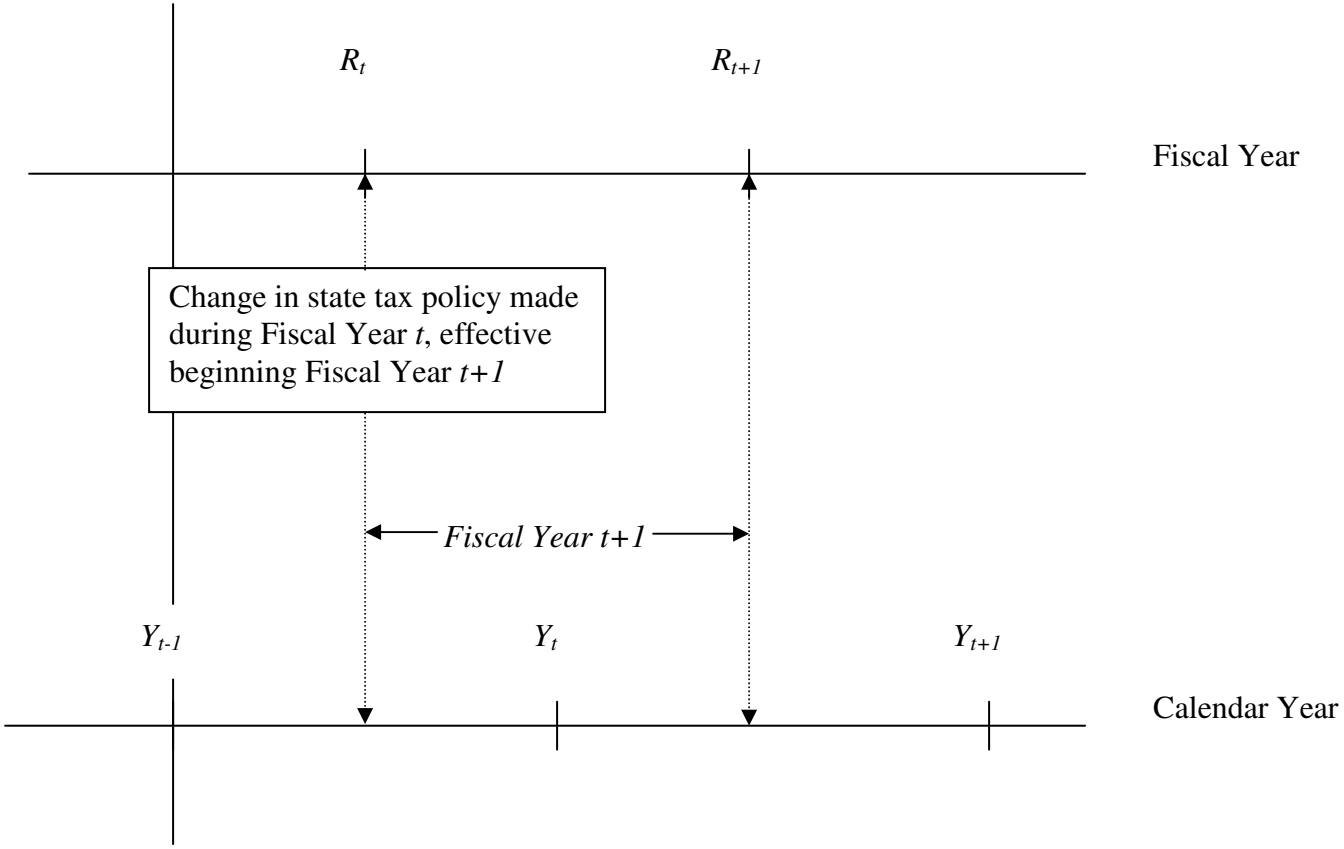
NOTES: The NASBO estimates run through 2002, while the NCSL-B estimates only extend through 1998. *Tax Burden* measures the ratio of total state tax revenues over total state Personal Income.

FIGURE 5
***Tax Burden* Versus Changes in State Tax Policy: United States**



NOTES: The NASBO estimates run through 2002, while the NCSL-B estimates only extend through 1998. *Tax Burden* measures the ratio of total state tax revenues over total state Personal Income.

FIGURE 6
The Real Time Relationship Between Changes in State Tax Policy and Income



APPENDIX
A Calculation of the Error Associated with Measuring $\frac{\Delta Taxes_{st}^{True}}{Y_{s,t-1}}$ with $\frac{\Delta Taxes_{st}^{Forecast}}{Y_{st}^{F}}$ when $\Delta\beta_{0,st} \neq 0$

We define the error associated with measuring $\frac{\Delta Taxes_{st}^{True}}{Y_{s,t-1}}$ with $\frac{\Delta Taxes_{st}^{Forecast}}{Y_{st}^{F}}$ when $\Delta\beta_{0,st} \neq 0$ by

$$\text{(A1)} \quad Error = \frac{\left(\frac{\Delta Taxes_{st}^{Forecast}}{Y_{st}^{F}}\right) - \frac{\Delta Taxes_{st}^{True}}{Y_{s,t-1}}}{\frac{\Delta Taxes_{st}^{True}}{Y_{s,t-1}}}.$$

Substituting Equations (3) and (7) into (A1) yields

$$\text{(A2)} \quad Error = \frac{\left(\frac{\Delta\beta_{0,st} + \Delta\beta_{1,st} \cdot Y_{st}^{F}}{Y_{st}^{F}}\right) - \left(\frac{\Delta\beta_{0,st} + \Delta\beta_{1,st} \cdot Y_{s,t-1}}{Y_{s,t-1}}\right)}{\left(\frac{\Delta\beta_{0,st} + \Delta\beta_{1,st} \cdot Y_{s,t-1}}{Y_{s,t-1}}\right)}.$$

Algebraic manipulation allows us to rewrite (A2) as follows,

$$\text{(A3)} \quad Error = \frac{\Delta\beta_{0,st}\left(\frac{Y_{st}^{F}}{Y_{st}^{F}}\right) - \Delta\beta_{0,st}}{\left(\Delta\beta_{0,st} + \Delta\beta_{1,st} \cdot Y_{s,t-1}\right)}.$$

Note that when $\Delta\beta_{0,st} = 0$, $Error = 0$.

Define k_{st} such that

$$\text{(A4)} \quad \Delta\beta_{0,st} = k_{st} \cdot \left(\Delta\beta_{1,st} Y_{s,t-1}\right).$$

Thus, if $k_{st} = 1$, the component of total new taxes that is independent of state income, $\Delta\beta_{0,st}$, is equal to the component of total new taxes that is dependent on the value of state income, $\left(\Delta\beta_{1,st}Y_{s,t-1}\right)$.[25] Substituting (A4) into (A3) and doing some manipulation yields,

$$\text{(A5)} \qquad Error = \frac{-k_{st}\left(1 - \frac{Y_{s,t-1}}{Y_{st}^{F}}\right)}{1 + k_{st}}.$$

We now define a new variable, g_{st}, such that

$$\text{(A6)} \qquad Y_{st}^{F} = \left(1 + g_{st}\right) \cdot Y_{s,t-1}.$$

Thus, g_{st} is the forecasted annual growth rate of Personal Income. Substituting (A6) into (A5) and performing some algebraic manipulation yields

$$\text{(A7)} \qquad Error = \frac{-k_{st}\left(\frac{g_{st}}{1 + g_{st}}\right)}{1 + k_{st}}.$$

We are now in a position to estimate the size of the error. The annual growth rate of (nominal) state Personal Income from 1970-2000 is approximately 6%. Further, it is unlikely that the changes in total taxes that were independent of income would ever be as large as the portion that is dependent on income. Accordingly, if we substitute "upper bound" values of $g_{st} = 0.10$ and $k_{st} = 1$, we get $Error = -0.045 = -4.5\%$. This constitutes the basis for our claim in the text that "the error associated with measuring $\frac{\Delta Taxes_{st}^{True}}{Y_{s,t-1}}$ by $\frac{\Delta Taxes_{st}^{Forecast}}{Y_{st}^{F}}$ when $\Delta\beta_{0,st} \neq 0$ will generally be less than 5%."

[25] Strictly speaking this should read, "the component of total new taxes that is dependent on the value of state income *assuming state income stays constant."*