Center for Research On the Wisconsin Economy
University of Wisconsin- Madison

State-Level Implications of Federal Tax Policies

Chang Liu and Noah Williams

Center for Research on the Wisconsin Economy, UW-Madison

December 7, 2018

Abstract

The United States federal fiscal policy has differential impact across states. We construct a new quarterly state-level dataset that we use to analyze the impact of unexpected changes in federal personal and corporate income taxes. We find substantial heterogeneity across states, with more than half having no significant response to the tax cuts. In addition, less capital intensive states have larger responses to corporate tax cuts. Although puzzling in standard models, a model with corporate and non-corporate sectors is consistent with this evidence. Overall, our results suggest the importance of variation and reallocation across states in evaluating federal policy.

1 Introduction

The United States provides a rich environment to study economic dynamics and the impact of economic policy. The states are the well-known "laboratories of democracy" and their differing experiences can shed light on a number of important issues. The diversity of different statewide and regional factors and policies allows for many interesting interactions and comparisons. In addition, the commonality of national factors, federal fiscal policy, and monetary policy can potentially allow for a clear isolation of sources of difference. In essence, the United States consists of a monetary and fiscal union, with fifty small open economies that each control an additional layer of state fiscal and regulatory policy. A growing body of research has used this regional variation across states to inform estimates of policy impacts and sources of fluctuations. In this paper we analyze the differential impact across states of changes in the common federal tax policy, which helps us understand the channels of policy impact.

Recent studies find large and significant *aggregate* expansionary effect of tax cuts, for example, Blanchard and Perotti (2002), Romer and Romer (2010), Mertens and Ravn (2013) among others. This paper builds on but departs from this literature by investigating the *regional* effects of unanticipated changes in both federal personal and corporate income tax, using more than 50 years of data at the state level. We find that given an unanticipated negative federal personal or corporate income tax shock, the output or employment responses are significantly positive for less than half of the states, not significantly different from zero for over a half of the states, and that a few states respond to neither tax change significantly. There are more states showing significantly positive output or employment responses to a corporate than personal income tax cut, but the average responses to the latter are higher. Our results imply that the positive aggregate output responses to either personal or corporate income tax cut, as found in various previous studies, may have been driven by only a small number of states. Therefore it's important to look beyond the aggregate macro data and investigate the differential effects of a nationwide policy from a regional perspective. In particular, as we discuss below, our results suggest that factor reallocation across states and sectors plays an important role in generating the aggregate impacts of federal tax changes.

Our empirical results are drawn from two main datasets. First, we compile from various sources a state-level raw dataset of the key macro variables. However, most of the macro data at the state level are either missing, incomplete or only available at low frequency, thus not suitable in studying many macro issues, which typically rely on data at a quarterly frequency (or higher). We produce a relatively balanced state-level historical dataset, employing the mixed-frequency VAR method proposed by Schorfheide and Song (2015), who used it in a forecasting framework using aggregate data with different frequencies. Second, we extend the time series of narrative federal personal and corporate income tax shocks in Mertens and Ravn (2013), following Romer and Romer (2010)'s account of changes in US federal tax liabilities, and eliminating the "anticipated" tax policy changes with implementation lags longer than a quarter.

Our state-level estimation follows the "proxy structural vector autoregression (SVAR)" method described in Mertens and Ravn (2013). By proxying latent structural tax shocks with narratively identified tax liability changes of federal taxes in a SVAR framework, this methodology has obvious advantages in circumventing the strong identification assumptions in previous versions of SVAR, and the unavoidable measurement error issue in the narrative approach, see discussions in Mertens and Ravn (2014). In particular, we assume that the narrative tax changes are uncorrelated with macro fundamentals because of the way they are constructed, and allow them to be correlated with the structural tax shocks because of, say, measurement errors. As in Mertens and Ravn (2013), we impose additional restrictions between the reduced-form VAR residuals and the structural shocks in order to separately identify the effect of one tax shock controlling for the other one. We then make inferences on the impulse responses of state-level macro variables to either structural tax shock.

We find substantial heterogeneity in our point estimates of the responses of state output to either tax cut: the peak GDP increases range from 1% – 7% in response to a 1 percentage point cut in the average personal income tax rate, and 0 – 1.5% when there's a 1 percentage point cut in the average corporate income tax rate. Once considering the statistical significance of these estimates, we notice that more than half of the states do not have a significant response to either tax cut, even more striking evidence of state-level heterogeneity.

We proceed to study what state-level characteristics may explain these heterogeneous

responses. We focus on two possible candidates: the state tax structure (measured by the average state personal income, corporate income and sales tax rates), and the state economic structure (measured by the overall capital share of income). States differ substantially in the overall level and composition of their tax systems, and when combined with federal taxes, this leads to different effective tax rates across states. Thus one may expect differential impacts of federal tax policies which operate on the same margins as federal taxes, as the state taxes are compounded by federal taxes. However we find relatively little evidence of this impact. The variation in state tax structure doesn't seem to consistently explain the heterogeneous state-level responses we observed.

Turning to the economic structure, McMurry and Williams (2018) document substantial heterogeneity in the factor intensities of production in different states. Industries are not uniformly spread across the United States, and this differential industry composition along with variation of factor-intensities within industries leads to different estimates of the state-level factor shares. Across several specifications, We find robust evidence that output responses to a 1 percentage point corporate tax cut are negatively correlated with the average state capital share of income across all of our specifications: a 1 percentage point higher capital share is associated with lower cumulative responses of output and employment, by $0.7 - 0.9\%$ over a 5-year horizon.. Most of our specifications also show a negative relationship between the employment response to a corporate tax cut and capital share as well, albeit of a smaller magnitude.

This result is striking because it is runs counter to most standard macro models used to study the dynamic impact of taxation. In a standard one-sector model, it is natural to assume that all production is done by corporations. In this case, with competitive markets the corporate income tax is equivalent to a tax on capital income (making the common assumptions that investment is financed by equity). Thus we would expect the effect of a cut in the corporate tax to have the largest effect in economies (or states) which are most capital intensive. That is, states with a larger share of capital income use capital more intensively in production, and accumulate larger capital stocks. A reduction in the corporate tax thus affects a larger tax base, driving larger changes in incomes, and leading to a larger impact on output. We illustrate these effects in a number of one-sector models, showing that

the conclusions are not affected by the details of the market structure, trade, or frictions. These additional features may affect the short-run impact of the tax changes, but are not enough to change the long-run or cumulative response.

While in one-sector models the corporate tax is a tax on capital, it is really a tax on the capital and profits of a particular type of business. In addition, although in the past most of US output was produced by corporations, this is no longer the case. In recent years the share of pass-through businesses, which are taxed as income to owners rather than through the corporate tax, has grown and now makes up a majority of economic activity. As we discuss, the traditional analysis of the incidence of corporate taxes, following Harberger (1962), focuses on the mobility of factors across sectors as well as states. Thus we focus on a small open economy model with the addition of a non-traded corporate sector, whose good (services, for example) must be supplied by domestic producers. We show that such a two-sector model can explain, at least qualitatively, our empirical finding of a larger output response to a corporate tax cut with a smaller capital's share of income. The key to this result in our model is that the larger overall capital's share in the state results from a disproportionate increase in the capital intensity of the non-corporate sector.

Overall our results point to the importance of regional variation in understanding the impact of policy changes, and suggest that factor reallocation across states and sectors plays an important role in generating the aggregate impacts of federal tax changes. The remainder of this paper is organized as follows. Section 2 discusses the data, empirical strategy and main results. Section 3 discusses the theoretical models we use to understand the empirical results. Section 4 concludes.

2 Empirical Findings

Our state-level estimation is based on two datasets: a quarterly state-level macro dataset estimated using the mixed-frequency VAR approach developed by Schorfheide and Song (2015), and narrative federal personal and corporate income tax shocks à la Mertens and Ravn (2013), which in turn is based on Romer and Romer (2010). To identify the state-specific dynamic effects of federal tax changes, we follow closely the estimation and identification

strategy of Mertens and Ravn (2013).

2.1 A Quarterly State-level Macro Dataset

Most of the postwar macro data in U.S. are available at the quarterly frequency or higher. This makes it convenient for macroeconomists to study the aggregate economy using national-level data. However, most state-level macro data are either missing, incomplete, or only available at the annual frequency. For example, capital and investment data are not readily available from any public source; personal consumption expenditure (PCE) is only available in BEA Regional Accounts since 1997; and there's no quarterly GDP data until 2005. Table 1 displays our collection of the main state-level variables, together with their sample period, frequency, source and additional notes.[1] Our sample period is 1963-2017. All the quarterly or monthly series, if necessary, have been seasonally adjusted using the Census X-13ARIMA-SEATS seasonal adjustment program. Nominal GDP and consumption data are transformed to their real counterparts in chained 2009 million dollars. More details for data construction are relegated to Appendix A.1.

[Table 1 here]

To estimate a balanced panel of quarterly state-level dataset, we employ the mixed-frequency VAR estimation methods in Schorfheide and Song (2015), in which the main purpose is to compare the forecast performance of a standard quarterly-frequency VAR with that of a mixed-frequency one, and the estimated monthly historical series are their by-products. We analogously infer the quarterly components of the annual observations to construct a balanced state-level time series, but depart from their approach in the following ways. First, our framework is more flexible in allowing for the change in observation frequency (e.g. GDP and Tax Revenue), as well as missing observations (e.g. Unemployment Rate before 1976). Second, in addition to the state data, we add their national counterparts and financial variables (Treasury Bond Yield, Fed Funds Rate, and Corporate Bond Yield) as

[1]Since there's much shorter sample for consumption and the estimated data is sensitive to the choice of initial distribution in the Bayesian estimation, we remove this variable from our estimation sample in this paper.

separate "national block" regressors. Table 4 in Appendix A.1 lists all the variables included in the national block.

In particular, we assume that each state economy evolves at quarterly frequency according to the following *state-transition equation*:

$$x_t = \sum_{i=1}^{p} \Phi_i^s x_{t-i} + \sum_{j=0}^{q} \Phi_j^n y_{t-j} + \Phi^c + u_t, u_t \sim i.i.d.N(0, \Sigma)$$

where x_t is a $n \times 1$ vector of state macro variables that contains n_a variables observed at the annual frequency (log real GDP, log state government expenditure, log real capital, log state tax revenue, log CPI) and n_q variables observed at the quarterly frequency (log personal income, log total non-farm employment, and unemployment rate); y_t is a vector of national variables that is assumed to be exogenous to the state economy; Φ_i^s and Φ_j^n are the coefficients on lagged state and national variables respectively; Φ^c is a vector of constants; p and q are the lags included in state and national variables; the error vector u_t is assumed to be $i.i.d.$ and follow a multivariate normal distribution. Based on some preliminary exploration of the marginal data density, we set the number of lags in the quarterly state transition of the mixed-frequency VAR to 4 and assume no lags in the national block so that the state economy is only affected by contemporaneous national economic conditions.

The *measurement equation* of the state-space representation is imposed in a way that annual observations are equal to the average of their quarterly latent components for the five variables that are observed at the annual frequency in x_t. In the Bayesian estimation stage, we assume the Minnesota prior distribution for (Φ, Σ), where $\Phi = (\Phi_1^s, ..., \Phi_4^s, \Phi_0^n, \Phi^c)$; compute the conditional posterior distribution of latent variables and estimation parameters using the standard Kalman filter; Gibbs sample over the two conditional posterior densities; and take the median of the latent variable distribution as our estimates for the quarterly components of the n_a annually-observed variables. Since this paper mainly focuses on the state-level impact of federal tax shocks, we don't fully describe the estimation process here. A companion paper Liu and Williams (2018) has a detailed account of the state-space formulation, prior distribution assumption, hyperparameter selection, initial sample distribution etc. for the updated mixed-frequency VAR model. Curious readers may also refer to Schorfheide

and Song (2015) who lay the foundation of our main strategy.

Figure 1 shows the estimated (blue line) against raw (red circle) series of some key variables in an example state, California. Table 2 provides summary statistics of some key variables in our sample. For the key economic indicators like personal income, GDP and employment growth, we consistently observe cross-state heterogeneity in the mean growth rates, cross-time standard deviation of growth rates, and the correlation between state-level and aggregate growth. For instance, the average U.S. GDP growth in our sample period is 2.88%, but the state-level GDP growth ranges from 1.64% to 4.53%, indicating even bigger long-run growth gaps. Standard deviation of state-level growth also tends to be widely dispersed, and for most of the states, output growth is on average more volatile than the U.S. as a whole, indicating a cross-state smoothing effect of growth volatility. The correlations between state-level and aggregate output growth are on average low, and widely dispersed across states too.

In sum, there's substantial cross-state heterogeneity in our state-level macro dataset, and the state-level data are only weakly correlated with their aggregate counterparts, both of which point to the necessity to go beyond the aggregate data to study the policy impacts. In this paper, we explore this vein in a particular setting: the impact of federal tax policy changes.

[Figure 1 here]

[Table 2 here]

2.2 Narrative Federal Personal and Corporate Income Tax Shocks

Mertens and Ravn (2013) document the exogenous narrative exogenous federal tax changes for personal and corporate income ΔT_t^{PI} and ΔT_t^{CI}, calculated by the legislated tax liability changes in individual income and employment taxes over personal taxable income of the previous period, and the legislated changes in corporate income tax liability over corporate profits of the previous period. Motivated by the narrative approach of Romer and Romer (2010), they include only the "exogenous" tax changes in this sample, including those motivated by long-run growth prospects and those made to deal with an inherited budget deficit

not related to current economic conditions or spending changes; exclude the "endogenous" ones like countercyclical policy changes and spending-driven changes made to counteract the government spending. We extend their dataset up to 2017. In particular, we add two personal income tax changes (the Tax Relief, Unemployment Insurance Reauthorization and Job Creation Act of 2010, and the American Taxpayer Relief Act of 2012) and one corporate income tax change (the American Taxpayer Relief Act of 2012), following the rules of picking "exogenous" tax shocks and the additional rules in separating personal and corporate income tax shocks, as in Mertens and Ravn (2013). Details about this process can be found in Appendix A.2.

Our extended sample of narrative shocks for the period 1950Q1 – 2017Q4 is plotted in Figure 2. In identifying the effects of these tax shocks with the state level macro data, we use the subsample period 1964 Q1 – 2017Q4, which covers nearly all of the noted tax changes.

[Figure 2 here]

2.3 Main Estimation

With the state-level macro datasets, and narrative accounts of tax policy changes at the federal level, we proceed with our main questions: what are the state-level responses of federal tax policy shocks? Is there heterogeneity in those responses? What account for the differences?

To contrast the state-level responses with the aggregate ones, we follow closely the estimation strategy of Mertens and Ravn (2013): to exploit the information of narrative measures of tax changes for identification in a SVAR framework. We impose the same identification restriction that our narrative tax policy shocks are only correlated with the structural tax shocks, but not other macro shocks, which is even more validated in our setting if one considers each state as a small open economy. Besides, it's important to control for changes in the other tax rate when analyzing the effects of a shock to one tax rate change, since in our constructed sample personal and corporate tax changes are positively correlated. Same as in Mertens and Ravn (2013), we impose a parametric recursivity assumption of the relationship between reduced-form VAR residuals and structural shocks.

However, due to data limitations, our sample period (1964Q1 – 2017Q4) is different from theirs (1950Q1 – 2006Q4), and our state-level macro variables are not adjusted for state population. To make more sensible comparisons, we replicate their results using our sample period and aggregate macro data without adjusting for nationwide population. We show that across a wide variety of specifications, the main result still holds, that is, short-run output effects of tax shocks are large.[2] This is not surprising given that various studies have confirmed this result.

We estimate a SVAR for each state. In our benchmark analysis, four variables enter the proxy SVAR: average personal income tax rate (APITR), measured by (personal current taxes + contributions for government social insurance)/personal taxable income; average corporate income tax rate (ACITR), measured by taxes on corporate profits/corporate profits; logarithm employment; and logarithm real GDP. As the fiscal variables are the same across all the state-level regressions, this setting is in line with our main question, that is, the heterogeneous impacts of common shocks at the federal level. Our estimation sample covers the period 1964Q1 – 2017Q4, and the autoregressive lags are set to 4.

In each regression, we calculate the dynamic impulse responses of employment and GDP to a –1% federal personal and corporate income tax shock. For each response function, we rank by state the cumulative responses over a 20-quarter horizon. In the main text–for exposition purposes–we report the point estimates for only the 10th, 25th and 40th states, as shown in Figure 3, with the full results being relegated to Appendix B Figure 13. As the results for Alaska and Wyoming are clearly outliers for almost every result (benchmark and various robustness checks), they are not included in these graphs.

A –1% federal personal income tax shock leads to expansions of employment and GDP for most states (most of the impulse responses are above the x-axis). In these states, the peak responses of employment range from slightly lower than 1% up to 5%; and those of GDP range from 1% to 7%. Similarly, there are expansionary output and employment effects of corporate tax cut for most states, albeit the magnitudes of these responses are on average lower: from slightly above 0 to 1.5%. In a few states, the effect of tax cuts seems to be contractionary, but in the following analysis we show that most of these negative responses

[2]See Figure 12 in Appendix B.

are in fact not significantly different from 0.

[Figure 3 here]

Our analysis wouldn't be complete without discussion on the significance of these responses. We compute the 95% confidence intervals for each state-level estimation using the recursive wild bootstrap with 10,000 replications, and replace the point estimate with 0 if it isn't significantly different from 0 at the 95% level. Though not perfect, we believe this measure generates conservative estimates of the actual effects of tax policy changes. Figure 4 shows the impulse responses when we take into account the significance of an estimate. For both personal and corporate income tax changes, there are 1-3 states that respond quite differently from the rest: expansionary tax changes are contractionary in these states. Since the number of these states are small, in this paper we do not specifically investigate why these states respond so differently, but focus on the rest of the sample.

Our result shows that more than a half of the states do not respond significantly to either personal or corporate income tax change at any point within the 20-quarter horizon. A small subset of them respond to neither. For the states that do respond to either tax cut, the responses of employment and GDP are almost always positive, although the magnitude and persistence of these effects are quite heterogeneous too. Compared with corporate income tax, the magnitude of impact (if there's any) on personal income tax change is bigger, but fewer states have significant responses. Given that we use the same methods, our result is in clear contrast with but not necessarily contradicts the conclusions in previous literature drawn with national-level macro data; it indicates that the significant positive response of output (and others) that they find at the aggregate level might have been driven by just a few states, while the rest do not respond to these policy changes at all.

Similarly, we calculate and rank the cumulative responses adjusted for significance over a 20-quarter horizon. For the minimum and maximum responding states (among those that have non-zero cumulative responses), we report in Figure 5 the point estimates and their 95% confidence interval bands. Take the GDP response to corporate income tax cut as an example; there seems to be only a short-lived on-impact significant effect for Illinois, while for Rhode Island the responses are on average both much stronger and long-lasting.

[Figure 4 here]

[Figure 5 here]

2.4 What Accounts for the Differences?

Given the heterogeneous state-level responses of federal tax shocks, a natural question that follows is: what drives the heterogeneity? While we are not able to exhaust the possible candidates, we investigate in this paper two most likely ones: state tax and economic structure summarized by capital share of state income. Our state-level capital share series come from the calculation by McMurry and Williams (2018) [3]; average state individual income tax rate is from NBER TAXSIM; average state corporate income tax rate is from the calculation by Suárez Serrato and Zidar (2016); sales tax rate is from the Book of States. The average state tax rates and capital share of income are summarized in Table 5 in Appendix B.

As demonstrated by this table, state tax rates and capital share of income are quite heterogeneous. In fact, for each tax category there are at least five states that don't collect it at all over the past decades; and among those that do collect, the tax rates vary a lot. And capital share of income varies across regions too.

Tax policies at the federal level potentially have different effects on different states, depending on their economic and fiscal structures. A corporate tax cut, for example, would disproportionately boost states with different factor intensities. Meanwhile, we notice that both tax rates and tax bases vary considerably across states: sales, individual income and corporate income tax rates are widely dispersed across states. The interaction between state and federal tax is likely to be one of the driving forces behind the heterogeneity in federal tax impacts across states.

[3] McMurry and Williams (2018) estimate the state-level capital within an industry by allocating nationwide capital in that industry across states. In particular, they assume that capital is perfectly mobile within but not across sectors and that output market is perfect competitive. Let i denote the state, j the industry and t the time. Since $R_{ijt} = R_{jt}$, it follows that $K_{ijt} = \frac{R_{ijt}K_{ijt}}{R_{jt}K_{jt}}K_{jt}$. Since $R_{ijt}K_{ijt}$ and $R_{jt}K_{jt}$, as measures of capital income, are both observable in the BEA gross operating surplus (GOS) by state and industry, as well as K_{jt} as the nationwide capital by industry, they could estimate a capital series by state and industry (K_{ijt}), summing up to a state capital series (K_{it}). Capital share of income at the state level is $\alpha_{it} = \frac{R_{it}K_{it}}{P_{it}Y_{it}}$, the numerator being payments to capital measured by GOS of state i and the denominator being the nominal GDP of state i.

We measure the overall tax response by summing up the responses over a horizon of 20 quarters by state, both ignoring and considering whether they are statistically significant. This measure of response could be interpreted as the cumulative tax effect over a horizon of 20 quarters, so we are not distinguishing between short and long-run impacts. In the next subsection we show that the statistical significance concern does not affect our result. Using peak response is not likely to change our results either since we observe that a state that has a high peak response also tends to have a big cumulative response.

In Figure 6, we plot the cumulative employment and GDP responses to a –1% personal and corporate income tax shock, against the average capital share of each state. Same as the results shown in Figure 4, the responses to personal income tax shock are either small or not significantly different from 0 for most states; corporate income tax cut leads to rises in employment and GDP for a larger number of states.

[Figure 6 here]

From Figure 6, we find that although the employment and output effects of a corporate tax cut are significant for only around half of the states, these states tend to feature *smaller* capital share. While for the states that have relatively high capital share, the responses are almost always not significant. Big output response to a personal income tax cut, however, tends to happen only to higher capital share states, but the relationship between capital share and employment response to personal income tax cut is unclear.

One may be worried that the measured state capital share may be correlated with the relative size of the corporate sector, thus confounding our interpretation. We take the average of IRS corporate tax collections by state as a percentage of state GDP for 1998-2016 when data on federal corporate tax revenue are readily available at the Tax Policy Center [4], and plotted that against average capital share over the same period in Figure 7. We observe no real relationship between the two and confirm that the relationship between state capital share and state-level responses to tax changes is not driven by the size of the corporate sector.

[Figure 7 here]

[4] https://www.taxpolicycenter.org/statistics/irs-collections-state-and-type-1998-2016

We test the above results controlling for the potential effects of state tax structure, and analyze the effect of capital share on tax responses in the following cross-sectional regression model:

$$r_i = \boldsymbol{\beta} \boldsymbol{X_i'} + \varepsilon_i \tag{1}$$

where r_i denotes the cumulative response of state i; $\boldsymbol{X_i}$ is a 1×5 vector that contains a constant 1, capital share, average state individual income tax rate, average state corporate income tax rate, and sales tax rate; $\boldsymbol{\beta}$ is the coefficient vector that is reported in Table 3 Panel A (the full sample of states) and B (Alaska and Wyoming excluded). Panel C reports the result when the three tax rates are replaced with each type of tax revenue as a fraction of total revenue, an ex-post measure of the state tax structure.

Across the three sets of regressions, the correlations between capital share and the output response to both federal corporate and personal income tax cut are significant. In particular, a 1% higher capital share is associated with 0.7% to 0.9% lower output response to corporate income tax cut and 2% – 3% higher output response to personal income tax cut. Capital share is also significantly associated with lower employment response to corporate tax cut, but the impact is relatively smaller. In Appendix B Table 6, we show that our result is robust if we construct the cumulative responses using only point estimates (without considering statistical significance).

We do find strong and robust negative correlation between average state personal income tax rate and the employment response to corporate tax cut: a state with lower average state personal income tax rate tends to have higher employment response to a federal corporate tax cut. However, unlike capital share, the variation in state tax structure doesn't seem to be an important and robust factor in explaining most of the heterogeneous responses of federal tax changes. This result is consistent with our finding in various model simulations where both state and federal tax rates are included.

[Table 3 here]

2.5 Robustness

In addition to the benchmark, we also explore several alternative specifications in our state-by-state SVAR framework. One may be concerned that our estimated state data may involve measurement errors. We report in Figure 14 and 15 the estimation result where only personal income and employment is in the SVAR. Both of them are available at quarterly frequency, so there are no measurement errors coming from the mixed-frequency VAR estimation. Still, there are big cross-state heterogeneity in employment and personal income responses to tax cuts.

In the benchmark estimation of Mertens and Ravn (2013), regression specification seems important for the quantitative results (but not qualitatively). For example, the output response to personal income tax cut is smaller and less persistent when federal government debt is removed from their estimation sample. Figure 16 plots the cumulative response of each state against its average state capital share, where we add state government expenditure to the benchmark SVAR framework. The relationship between responses to personal income tax shock and capital share is much weaker; but our main result on the effect of corporate income tax cut is quite robust: states that have bigger responses to corporate income tax cut tend to have lower capital share of income.

The relationship between corporate tax responses and state capital share is also robust when we calculate the cumulative tax response using the point estimates without regard to whether it's statistically significant at the 95% confidence level, as is illustrated in Table 6. In fact, the average across-state difference in the cumulative response of either employment or GDP to corporate income tax cut is even more pronounced for every 1% difference in the state capital share.

We also add three nationwide variables to the benchmark analysis: GDP, Government Spending and Debt, all in log real terms. In this way, we single out the fiscal policy impacts by controlling for the aggregate economic conditions. Still, we find substantial heterogeneity of state-level responses to federal tax changes. The negative relationship between average capital share and output response to the corporate income tax cut still holds. However, there are more states with significantly negative employment responses to corporate income

tax cut, a result that is puzzling but seemingly consistent with the finding in Mertens and Ravn (2013) that "changes in corporate taxes have much less pronounced effects on the labor market" drawn using nationwide data.

2.6 Summary of the Empirical Results

We analyze the state-level implications of federal personal and corporate income tax changes using our own constructed state-level quarterly macro dataset, and an extended sample of federal narrative tax shocks. In contrast to the past findings of strong and significant expansionary effects of both tax cuts at the aggregate level, we find that more than half of the U.S. states are (statistically) unresponsive to either tax cut, and some states respond to neither. We also find robust evidence that a state with higher capital share of income tends to have smaller output and employment responses to the federal corporate tax cut, while those responding the most to corporate tax cuts are almost always states with low capital share.

3 Modeling Impacts of Tax Changes

We now turn to some economic models to help understand our empirical results. We focus on our most robust empirical finding, that states with a lower capital's share of income have larger output responses to reductions in the federal corporate tax. This is also the most surprising result, as it is difficult to rationalize this pattern of response in a standard one-sector model. Across many settings, the cumulative impact of a capital tax shock on output is larger when the capital share is larger. However the size of effect on impact of the tax shock may be larger when the capital share is smaller, and reallocation of resources across state borders in response to the tax cut may increase this difference. This emphasis on reallocation leads us to study the reallocation of resources across sectors. We show that a two-sector model, with corporate and non-corporate sectors, can explain (at least qualitatively) the larger output response with a smaller capital's share. Barro and Furman (2018) consider a similar two-sector model in their evaluation of the 2017 federal tax reform. The key to establishing our result is that the larger overall capital's share in a state must

result from a disproportionate increase in the non-corporate sector.

While we do not focus on it here, most models also suggest that the impact of changes in federal taxes should depend on state tax rates. For example, states that have a high tax rate on one income source of income compound the distortions associated with federal tax rates on that income source. Thus in a high state-tax state, a cut in federal taxes will result in a proportionately larger reduction in distortions, which would translate into larger impacts on outcomes. However we find relatively little empirical evidence in support of these results. Instead, Table 3 presents some evidence that *lower* state personal income tax rates are associated with *larger* effects of federal corporate tax cuts. This pattern of cross-factor tax dependence is also surprising.

3.1 One-Sector Models

In a standard one-sector neoclassical growth model, it is common to assume that all production takes place in the corporate sector. In this case, assuming no pure profits in equilibrium and that investment is financed by equity, the corporate tax acts just like a tax on capital income. We show that in sector models corporate tax cuts have larger long run and cumulative output responses in more capital-intensive economies. This result is driven by the larger tax base to which the tax is applied, and this effect dominates other aspects of most models which may impact the short-run responses, such as labor force dynamics and various frictions. Multi-region models, which more explicitly model trade and have been used to study cross-state dynamics in the US, may also lead to enhanced impact responses due to factor reallocation. But it is difficult to rationalize our observed empirical result of a larger cumulative response to a corporate tax cut with a lower capital intensity.

The intuition for the relation between capital intensity and the output response to a corporate tax cut can be seen in a simple modification of the traditional Harberger (1962) analysis of the incidence of the corporate tax. In particular, consider a competitive firm with a standard Cobb-Douglas production function with capital share α facing a corporate tax of τ, and for simplicity assume that there are no depreciation deductions. Then the standard

optimality conditions will lead to:

$$\begin{aligned}(1-\tau)\alpha(K/N)^{\alpha-1} &= R \\ (1-\alpha)(K/N)^{\alpha} &= w,\end{aligned}$$

with R being the interest rate and w the real wage. Thus if we use lower case letters to denote percent (log) deviations following a change in the tax, we have approximately:

$$k - n = -\frac{1}{1-\alpha}(r+\tau),$$

which in turn implies:

$$y = n - \frac{\alpha}{1-\alpha}(r+\tau)$$

In the simple case of a small open economy, r is determined in the world market. Most US states are small relative to the whole country, and thus do not have much influence over national interest rates. Nonetheless, we would expect that changes in federal tax rates which affect all states would lead changes in the US interest rate. Ignoring this aspect for now, it is clear that the assumptions on factor supplies and mobility affect the magnitude of the change in output in response to a change in the tax. If labor is immobile and in elastic supply, as in Harberger's long run analysis, then the output response is solely due to changes in capital:

$$y = -\frac{\alpha}{1-\alpha}\tau.$$

Thus a cut in the corporate tax rate τ will have a larger effect in more capital-intensive economies with larger α. On the other hand if capital were immobile and labor free to adjust, then output would increase in an amount equal to the tax cut $y = -\tau$.

The same basic forces in the traditional static incidence analysis also arise in more modern dynamic general equilibrium settings. Of course one major difference is the inclusion of responses by households whose decisions on saving and employment are affected by taxation. In addition, the mobility assumptions on factors play more subtle roles as they are shifted dynamically. That is, the initial impact after an unexpected tax cut may differ from the cumulative or long-run response. This is particularly true if the model incorporates sources

of real or nominal frictions or adjustment costs, which may alter the dynamic pattern of response to changes in taxes.

[Figure 8 here]

In the appendix, we consider a variety of one-sector models which differ in their market structure, real or nominal rigidities, and assumptions on market completeness. While the response on impact and the dynamics are affected by the details of the models, in each case we find that the cumulative response to the corporate tax cut is larger when the economy is more capital intensive. Here we illustrate illustrative case. The model is a modification of a standard real business cycle model with government spending, proportional taxes on capital and labor, and lump sum taxes which ensure the government's budget is balanced. In particular, we consider a standard Cobb-Douglas production function (with varying α) and assume a representative household has additively separable preferences:

$$u(C, N) = \log C - \frac{N^{1+\eta}}{1+\eta}.$$

We suppose that the corporate or capital income tax is time-varying and follows the standard auto-regression:

$$\tau_{t+1} = \rho\tau_t + \varepsilon_{t+1}$$

The economy consists of three regions: two states and the rest of the country. Each region has a representative consumer and representative firm, where consumer preferences are the same but capital intensities differ across regions. We suppose that each state consists of 5% of total output, with one state being more and the other being less capital intensive than the rest of the country. We also suppose that there are complete markets, so there is consumption smoothing and risk sharing across regions. The results in Figure 8 show that trade across regions alters the responses of the states to the capital tax shock, by increasing the response on impact of the less-intensive state but prolonging the impact in the more-intensive state. Thus trade and factor reallocation matter, but they suggest larger cumulative responses with more capital intensity, counter to our empirical results.

3.2 Two-Sector Models

As reallocation seems to play an important role in explaining our results, we now turn to a two-sector model which includes corporate and non-corporate business sectors. While in one-sector models the corporate tax is a tax on capital, it is actually a tax on the capital and profits of a particular legal form of business. As pass-through businesses comprise and increasing share of the US economy, when evaluating corporate tax changes it is important to recognize, as Barro and Furman (2018) emphasize, that many businesses do not pay this tax. Moreover, the traditional analysis of the incidence of corporate taxes, following Harberger (1962), focuses on the mobility of factors across sectors as well as states. Thus we focus on a small open economy model with the addition of a non-traded non-corporate sector, whose good (services, for example) must be supplied by domestic producers. We assume that the corporate and non-corporate sectors draw on the same supply of labor, so changes in wages are an important linkage across sectors in the response to the tax cut.

3.2.1 A Static Model

We begin with a version of the traditional analysis of the incidence of the corporate tax, which began with Harberger (1962), and was extended to open economies in Kotlikoff and Summers (1986), Harberger (1995), and Randolph (2006), among others. As noted above, these static analyses are best interpreted as giving the long-run response of the economy to a permanent tax change. We adapt the discussion in Randolph (2006), but we focus on output responses rather than tax incidence.

As in our discussion above, we focus on percentage deviations in response to a tax change, and we assume (as in a small open economy) that equilibrium interest rates remain unchanged. We assume that the corporate sector (with a superscript C) and non-corporate sector (with superscript N) are both competitive and have constant returns to scale production technologies with different capital intensities. The firm factor demand optimality

conditions thus imply:

$$\begin{aligned} k^C - n^C &= w - \tau \\ k^N - n^N &= w, \end{aligned}$$

as only the corporate sector pays the tax, which increases its cost of capital. Both sectors earn zero profits and the corporate traded sector is the numeraire good which trades a world price, while p_N is the relative price of the domestic non-corporate good. Thus we have:

$$\begin{aligned} p^C &= \alpha_C \tau + (1 - \alpha_C) w = 0 \\ p^N &= (1 - \alpha_N) w. \end{aligned}$$

Together these imply $w = -\frac{\alpha_C}{1-\alpha_C}\tau$ and $p_N = -\frac{\alpha_C(1-\alpha_N)}{1-\alpha_C}\tau$. We suppose that the total supply of labor is fixed, which implies total changes in labor must cancel: $n_C N_C = -n_N N_N$. Finally, we assume that domestic consumers have a constant price-elasticity demand function for the non-corporate good, which implies $c_N = -\varepsilon p_N$.

Combining these expressions allows us to solve for the equilibrium response of each sector to the corporate tax change. In particular, focusing on labor we get:

$$\begin{aligned} n_N &= \frac{\alpha_N \alpha_C + \varepsilon \alpha_C (1 - \alpha_N)}{1 - \alpha_C} \tau \\ n_C &= -\frac{\alpha_N \alpha_C + \varepsilon \alpha_C (1 - \alpha_N)}{1 - \alpha_C} \frac{N_N}{N_C} \tau. \end{aligned}$$

Thus in response to a cut in the corporate tax ($\tau < 0$), employment increases in the corporate sector and falls in the non-corporate sector as workers move to the sector with increased labor demand. The magnitude of this reallocation depends on the relative sizes of the sectors and their capital intensities, as well as the elasticity of demand for the non-corporate good.

In the simple special case where $\varepsilon = 1$, the analysis simplifies. In this case, labor in the non-corporate sector bears all of the response to the tax cut, with $n_N = -w$ and $k_N = 0$. Moreover, if the corporate and non-corporate sectors have equal output shares, then from their factor demand conditions, the ratio of their employment is equal to the ratio of their

labor shares:

$$N_N/N_C = (1-\alpha_N)/(1-\alpha_C)$$

and therefore:

$$\begin{aligned} n_N &= \frac{\alpha_C}{1-\alpha_C}\tau \\ n_C &= -\frac{\alpha_C(1-\alpha_N)}{(1-\alpha_C)^2}\tau. \end{aligned}$$

Larger capital shares in the corporate sector α_C lead to larger employment responses in each sector and larger output responses, as in the one-sector model above. However increases in the capital share of the non-corporate sector α_N have no impact on the employment in the non-corporate sector, but lead to smaller employment responses in the corporate sector, and thus smaller output responses as well.

Intuitively, the changes in the corporate tax affect the non-corporate sector only through the effect on wages. A corporate tax cut leads to an increase in wages, and thus a reduction in non-corporate employment. For a given corporate tax cut, the percentage change in employment in the non-corporate sector is independent of the size of the non-corporate capital share. But when the non-corporate capital share is low, the non-corporate sector is more labor intensive. Thus the same percentage size reduction in non-corporate employment corresponds to a larger change in the number of workers who switch to the corporate sector. This in turn leads to a greater percentage increase in corporate employment, since the corporate employment base is smaller and thus the inflow of new workers has a greater impact. This reallocation of workers across sectors thus leads to a larger output response to a corporate tax cut with a smaller capital income share, but only if we view the changes in capital share as mainly arising from the non-corporate sector.

3.2.2 A Dynamic Model

We now show that these same forces apply in dynamic model and can generate results which are consistent, at least qualitatively, with our empirical results. As in one of the one-sector models we discussed on above, we consider a small open economy model with incomplete

markets. Now for simplicity we take the exogenous interest rate to be constant, and thus look just at the impact of the tax cut on a small open economy like a state. However now, unlike in the one-sector models above, production is split between a corporate and a non-corporate sector that produce different goods. Households consume C_t which is a CES aggregate of the goods produced in each sector:

$$C_t = \left(\phi_C^{\frac{1}{\eta}} C_{Ct}^{\frac{\eta-1}{\eta}} + (1-\phi_C)^{\frac{\eta-1}{\eta}} C_{Nt}^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}},$$

where ϕ_C the weight on the corporate good and η gives the elasticity of substitution. As $\eta \to \infty$ and $\phi_C \to 1$ the outcomes from this model converge to those from the one sector model. We focus on the case of $\eta = 2$, which is the same as the value Nakamura and Steinsson (2014) use for the substitution elasticity between domestic and foreign goods, but similar results hold for other elasticities. As in the static model above, the corporate good is numeraire and P_{Nt} is the relative price of the non-corporate good. Then the aggregate price level P_t satisfies:

$$P_t = \left(\phi_C + (1-\phi_C) P_{Nt}^{1-\eta} \right)^{\frac{1}{1-\eta}}.$$

As above, sectors differ in their capital share α_i, and each sector has its own capital stock and hires labor from a common pool of workers. We also add quadratic investment adjustment costs, which change the shape of the impulse response functions but do not affect any of the qualitative results.

[Figure 9 here]

Figure 9 illustrates how in our dynamic model reallocation across sectors occurs in response to a shock. We discussed this reallocation in the static model above, and it is the key difference between our one and two sector models. In particular, Figure 9 shows the responses of output and employment in the corporate and non-corporate sector to the corporate tax cut, along with the response of aggregate output and employment (which is the weighted average across sectors). We see that the sectoral responses are much larger in magnitude than the aggregate, with employment increasing sharply in the corporate sector but falling in the non-corporate sector in response to the cut. On net, this generates a positive

hump-shaped response of employment to the shock. Similarly, output jumps on impact in the corporate sector with the reallocation of workers, and continues to increase in a hump-shaped fashion as increased investment leads to a buildup of capital in the sector. In the non-corporate sector, output falls with the reallocation of factors to the corporate sector, and on-net the aggregate impact is a smaller positive but prolonged output response.

We now focus on impulse responses from the model for differing levels of the capital share parameters in the two sectors, α_C and α_N. In each case we calibrate the model so that 67% of output is produced in the corporate sector, which is roughly the long-run average share from the data. In practice this involves changing the consumption share parameter ϕ_C as we change α_C or α_N in order to keep the sector size constant. In the US, the share of business income from corporations has been trending down over time and this value is a rough midpoint. The exact value of the share of output produced by corporations is relatively unimportant for our qualitative results. But it is important that we keep it fixed across specifications, as it ensures that our results are consistent with our empirical finding above that the size of the corporate sector is uncorrelated with capital's share across states.

[Figure 10 here]

[Figure 11 here]

In Figure 10 and 11 we plot the impulse responses and cumulative responses of output to a corporate tax shock. In Figure 10 we fix capital's share in the non-corporate sector at $\alpha_N = 0.4$ and show the results for two different values of capital's share in the corporate sector α_C. Our results here are similar to those in one sector models, and also are consistent with the static model above. Increasing capital's share in the corporate sector leads to a larger response of output to a corporate tax shock, which runs counter to our empirical results above. Figure 11 considers a similar exercise, but now we fix capital's share in the corporate sector at $\alpha_C = 0.35$ and show the results for two different values of capital's share in the non-corporate sector α_N. Here we see that the response of output to the corporate tax cut, both on impact and cumulatively, is larger with a smaller non-corporate capital's share, which is consistent with our empirical results. The intuition for this result also consistent with the static model described above, as a smaller non-corporate capital share leads to a

larger reallocation of workers from the non-corporate to the corporate sector in response to the tax cut.

4 Conclusion

In this paper we have documented substantial heterogeneity across states in their responses to federal tax shocks. In addition to the sharp differences in the estimated magnitude of the responses, more than half of all states have no statistically significant response to either tax change. We also find robust evidence that states which have a smaller capital's share of income have larger output and employment responses to reductions in corporate tax rates. While this result is puzzling from the vantage point of a standard one-sector model, it is consistent with a model that includes corporate and non-corporate sectors. Overall, our results point to the importance of regional variation in understanding the impact of policy changes, and suggest that factor reallocation across states and sectors plays an important role in generating the aggregate impacts of federal tax changes.

Our results in this paper suggest new avenues for future research. In particular, our theoretical framework has suggested the importance of sectoral reallocation, but we have not directly tested the empirical importance of this mechanism. Several economic indicators, including the capital data from McMurry and Williams (2018), are available by state and industry, so this is a potentially viable. However one important qualification is that the data is broken out by industry, not by corporate or non-corporate status as the theory suggests is important. Nonetheless, the theory also has predictions for the relative movements in prices and wages across states in response to the corporate tax cut, which we could confront with the data. Moreover, we have more disaggregated data by industry at the state level. It would be worth investigating whether the results we have found for statewide aggregates also across industries within a state and within a given industry across states.

In addition, while our results show the importance of heterogeneity and interactions across states and sectors, the models we have analyzed here have been relatively limited along those dimensions. Further, we have shown that the theory can qualitatively match the empirical findings, but have not considered whether the model can fit the facts quantitatively. In

ongoing work we are considering a more complete multi-state equilibrium model which allows for rich interactions and dependencies across states. In addition to addressing differential responses to federal policy, this model will allow us to study a wide array of issues and allow for policy evaluation at the federal and state levels.

References

Barro, R. J. and J. Furman (2018). "Macroeconomic Effects of the 2017 Tax Reform". *Brookings Papers on Economic Activity 2018*(1), 257–345.

Beraja, M., A. Fuster, E. Hurst, and J. Vavra (2018). "Regional Heterogeneity and the Refinancing Channel of Monetary Policy". *The Quarterly Journal of Economics*, forthcoming.

Beraja, M., E. Hurst, and J. Ospina (2016). "The Aggregate Implications of Regional Business Cycles". *NBER Working Paper*.

Blanchard, O. and R. Perotti (2002). "An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output". *The Quarterly Journal of Economics 117*(4), 1329–1368.

Caliendo, L., F. Parro, E. Rossi-Hansberg, and P.-D. Sarte (2018). "The Impact of Regional and Sectoral Productivity Changes on the U.S. Economy". *The Review of Economic Studies 85*(4), 2042–2096.

Desmet, K. and E. Rossi-Hansberg (2014). "Spatial Development". *American Economic Review 104*(4), 1211–43.

Fajgelbaum, P. D., E. Morales, J. C. Suárez Serrato, and O. Zidar (2018). "State Taxes and Spatial Misallocation". *The Review of Economic Studies*, forthcoming.

Harberger, A. (1962). "The Incidence of the Corporation Income Tax". *Journal of Political Economy 70*, 15–240.

Harberger, A. (1995). "The ABCs of Corporation Tax Incidence: Insights into the Open-Economy Case". In *Tax Policy and Economic Growth*. Washington, DC: American Council for Capital Formation.

Kotlikoff, L. and L. H. Summers (1986). "Tax Incidence". In A. J. Auerbach and M. Feldstein (Eds.), *Handbook of Public Economics*, Volume 2. Amsterdam: North-Holland Press.

Liu, C. and N. Williams (2018). "Implications of a Quarterly State-level Dataset". *manuscript*.

McMurry, J. and N. Williams (2018). "Capital and Productivity in U.S. States". *manuscript*.

Mertens, K. and J. L. Montiel Olea (2018). "Marginal Tax Rates and Income: New Time Series Evidence". *The Quarterly Journal of Economics 133*(4), 1803–1884.

Mertens, K. and M. O. Ravn (2013). "The Dynamic Effects of Personal and Corporate Income Tax Changes in the United States". *American Economic Review 103*(4), 1212–47.

Mertens, K. and M. O. Ravn (2014). "A Reconciliation of SVAR and Narrative Estimates of Tax Multipliers". *Journal of Monetary Economics 68*, S1–S19.

Nakamura, E. and J. Steinsson (2014). "Fiscal Stimulus in a Monetary Union: Evidence from US Regions". *American Economic Review 104*(3), 753–92.

Ospina, J. (2017). "Regional Business Cycle Accounting and the Great Recession". *manuscript*.

Ramey, V. A. and S. Zubairy (2018). "Government Spending Multipliers in Good Times and in Bad: Evidence from US Historical Data". *Journal of Political Economy 126*(2), 850–901.

Randolph, W. C. (2006). *"International Burdens of the Corporate Income Tax"*. Congressional Budget Office Washington, DC.

Romer, C. D. and D. H. Romer (2010). "The Macroeconomic Effects of Tax Changes: Estimates Based on a New Measure of Fiscal Shocks". *American Economic Review 100*(3), 763–801.

Schmitt-Grohé, S. and M. Uribe (2003). "Closing Small Open Economy Models". *Journal of International Economics 61*(1), 163–185.

Schorfheide, F. and D. Song (2015). "Real-Time Forecasting With a Mixed-Frequency VAR". *Journal of Business & Economic Statistics 33*(3), 366–380.

Suárez Serrato, J. C. and O. Zidar (2016). "Who Benefits from State Corporate Tax Cuts? A Local Labor Markets Approach with Heterogeneous Firms". *American Economic Review 106*(9), 2582–2624.

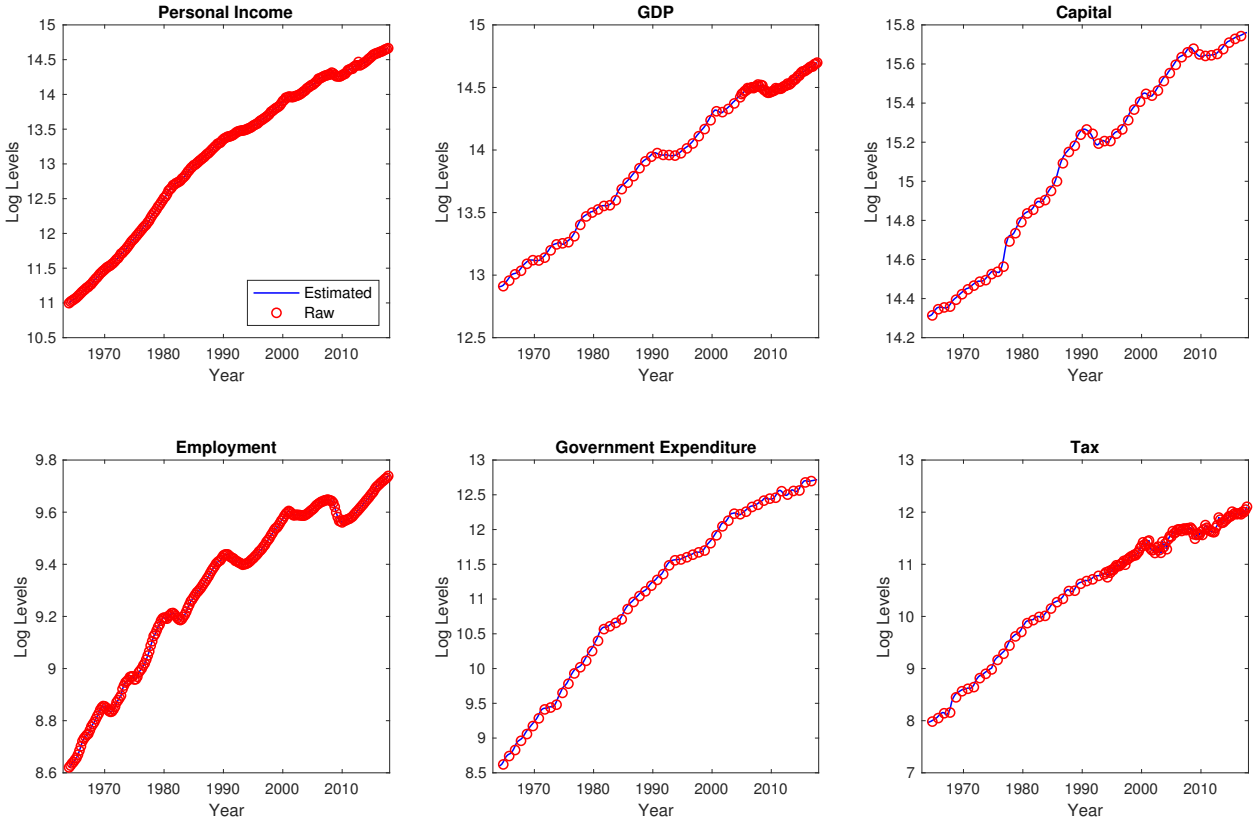
Zidar, O. (2018). "Tax Cuts for Whom? Heterogeneous Effects of Tax Changes on Growth and Employment". *Journal of Political Economy*, forthcoming.

5 Tables and Figures

Table 1: List of State-level Macro Variables in the Estimation Sample

Variable Name	**Span and Frequency**	**Source**	**Notes**
Personal Income	1948 – , Q	BEA	nominal
Total Nonfarm Employment	1939 – , M	BLS	seasonally unadjusted before 1990
GDP	1963 – 2005, A; 2005 – , Q	BEA	1963 – 1987: nominal, 1972 SIC; 1987 – 1997: 1987 SIC; 1997 – : 2007 NAICS
Government Expenditure	1951 – 2016, A	Census	nominal
Capital	1963 - 2016, A	McMurry and Williams (2018)	
State Tax Collection	1951 – 1993, A; 1994 – 2017, Q	Census	1951 – 1993: nominal; 1994 – 2017: nominal, seasonally unadjusted
Unemployment Rate	1976 – , M	BLS	
PCE	1997 – 2016, A	BEA	nominal
CPI	1950-2017	extension of Herkenhoff, Ohanian and Prescott (2018)	

Figure 1: Quarterly Data Estimates: California



Notes: plotted period: 1964 – 2017; frequency: quarterly.

Table 2: Summary Statistics of Key Variables

	U.S.	10th State	Median State	40th State
			Real Personal Income	
Mean Growth (%)	3.08	2.33	2.84	3.46
S.D. Growth (%)	3.23	3.76	4.46	5.48
Corr. with U.S.	1	0.52	0.64	0.72
			Real GDP	
Mean Growth (%)	2.88	2.29	2.91	3.58
S.D. Growth (%)	3.24	3.62	4.16	5.50
Corr. with U.S.	1	0.31	0.53	0.64
			Employment	
Mean Growth (%)	1.75	1.22	1.89	2.30
S.D. Growth (%)	2.14	2.57	2.90	3.38
Corr. with U.S.	1	0.64	0.76	0.85
			Price Index	
Mean Growth (%)	3.87	3.59	3.67	3.69
S.D. Growth (%)	3.07	2.36	2.40	2.49
Corr. with U.S.	1	0.78	0.81	0.84

Notes: sample period: 1964Q1-2017Q4. We compute the U.S. real personal income, real GDP, employment, and price growth using U.S. quarterly aggregate data; and the state-level growth using our estimated state quarterly growth data. We separately rank each summary statistic by state, and report that of the 10th, median and 40th state. So the values in each column (except for column "U.S.") may correspond to different states.

Figure 2: Narrative Shocks: 1950Q1 – 2017Q4

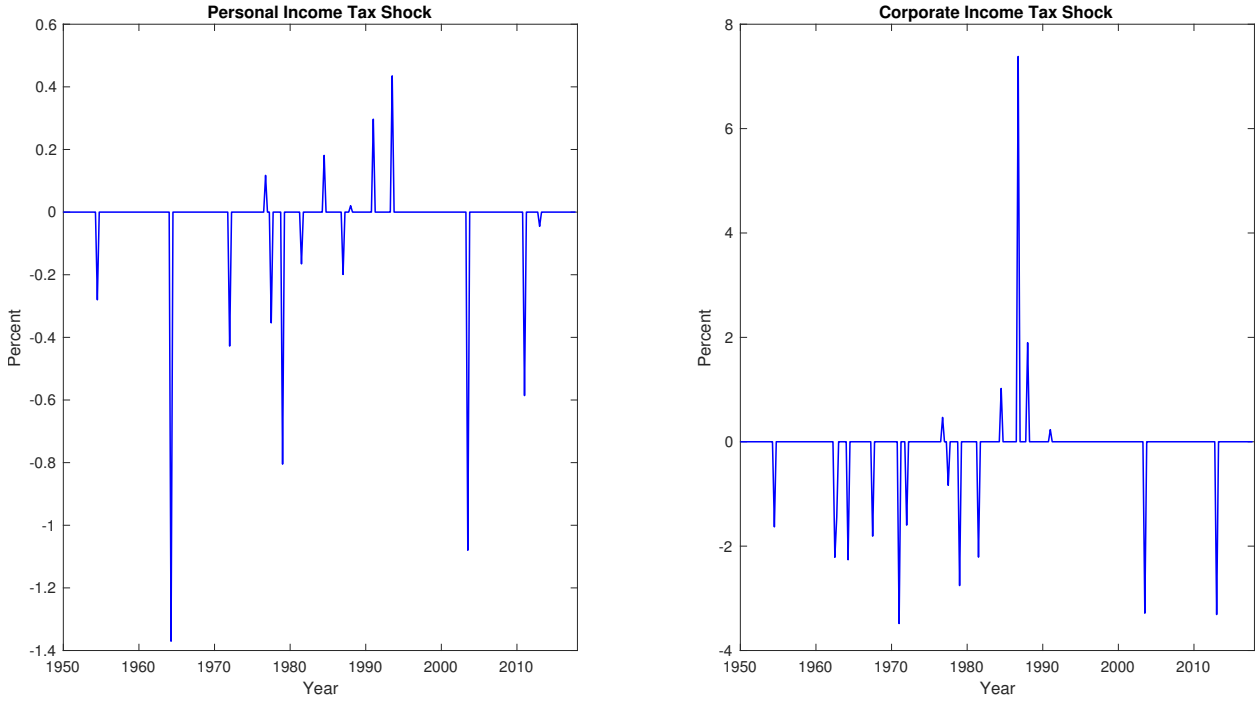
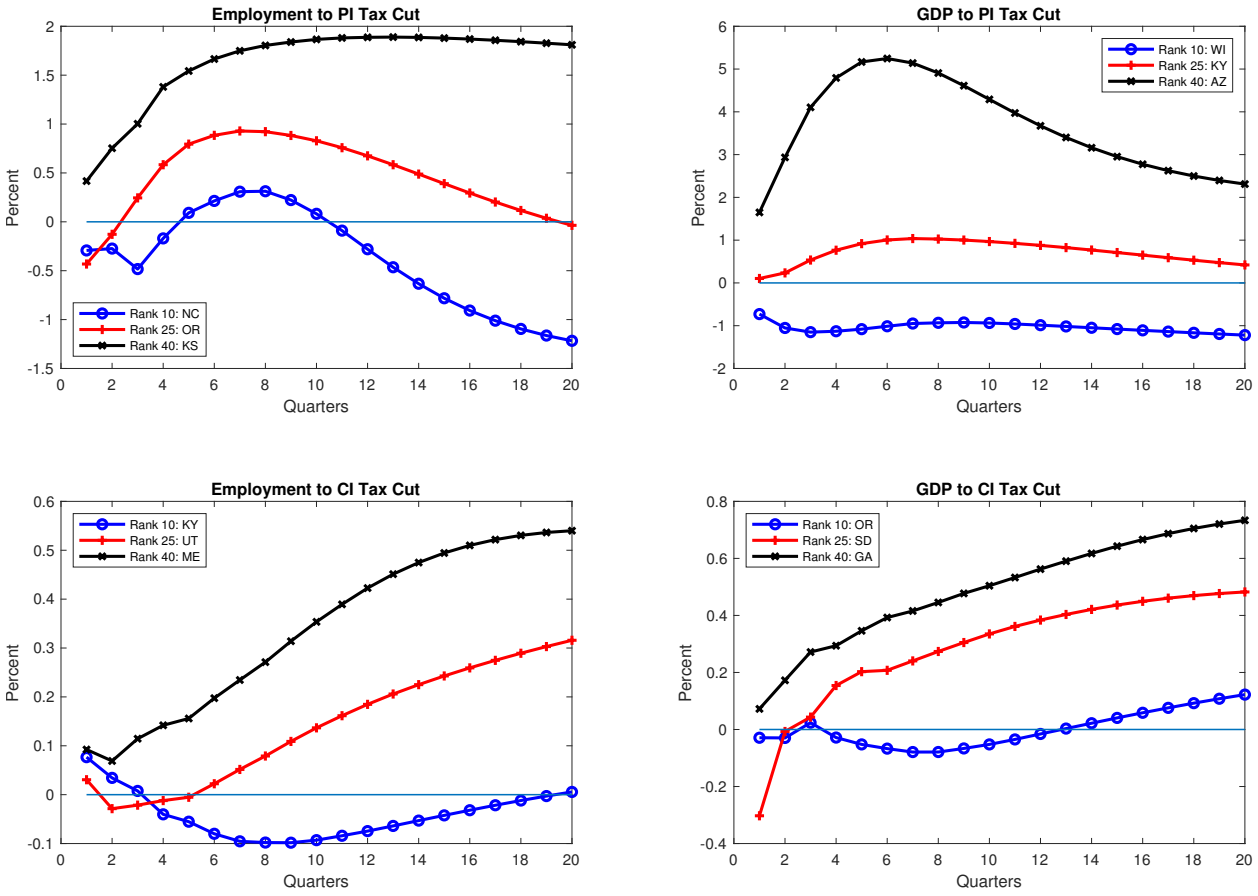
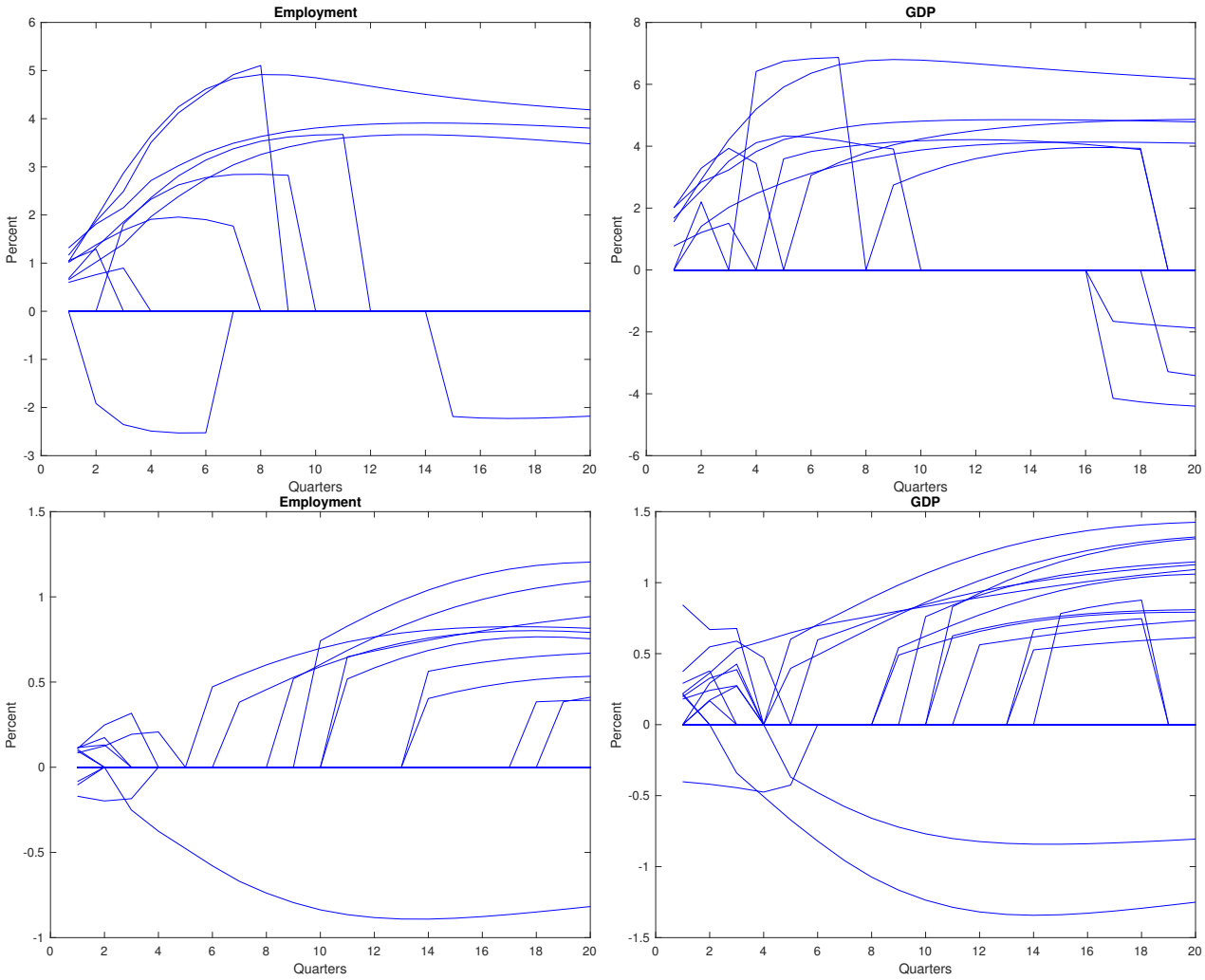


Figure 3: Benchmark Impulse Responses: 10th, 25th and 40th States Ranked by Cumulative Responses



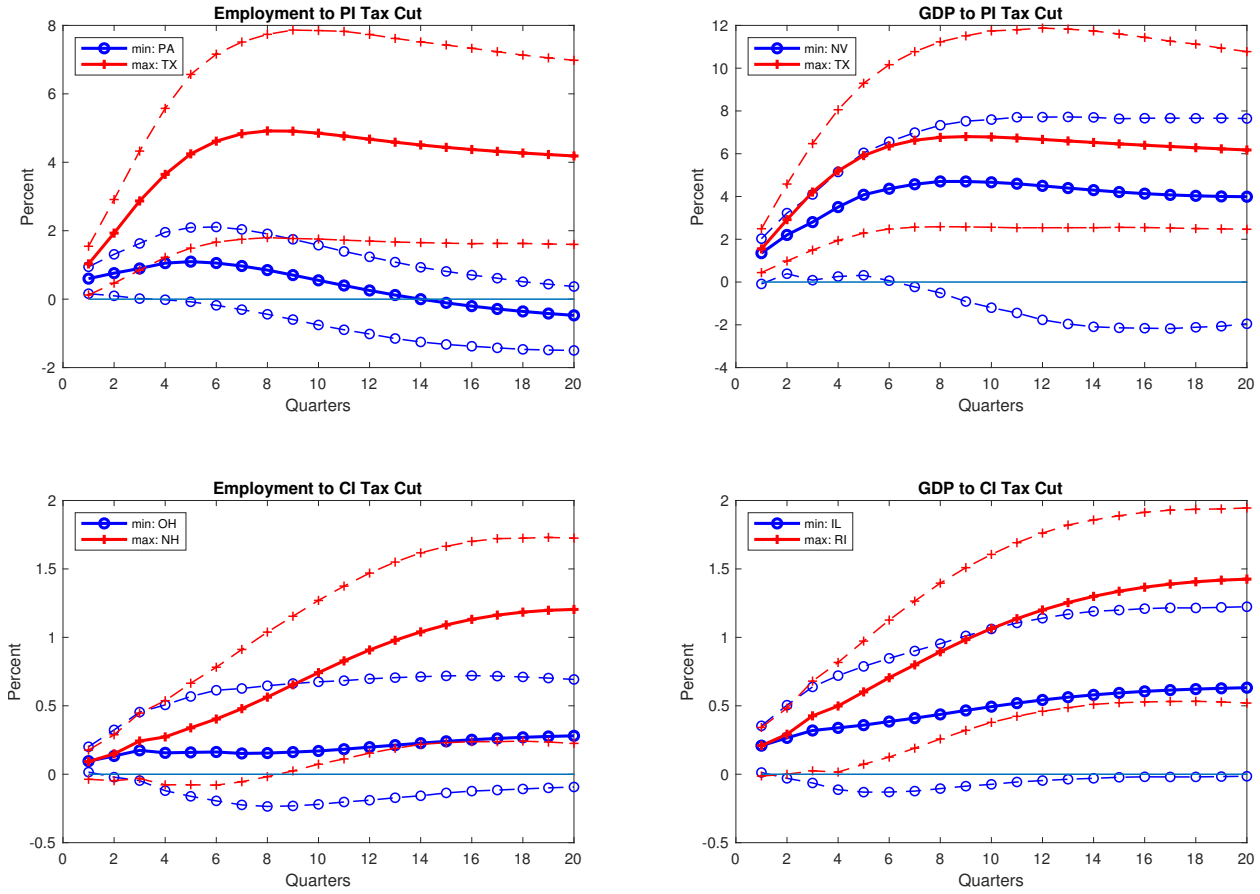
Notes: The top two figures show the impulse responses of employment and GDP to a -1% shock to the average federal personal income tax rate, where APITR is ordered second in the SVAR; the bottom two figures show the impulse responses of employment and GDP to a -1% shock to the average federal corporate income tax rate, where ACITR is ordered second in the SVAR. States are ranked by their cumulative impulse responses over a 20-quarter horizon. The 10th, 25th and 40th states in each ranking are displayed here.

Figure 4: Impulse Responses: Benchmark (insignificance set to 0)



Notes: In this figure, if 0 lies within the 95% confidence interval of the impulse response of a given variable at a given time, it is set to 0. The top two figures show the impulse responses of employment and GDP to a -1% shock to the average federal personal income tax rate, where APITR is ordered second in the SVAR; the bottom two figures show the impulse responses of employment and GDP to a -1% shock to the average federal corporate income tax rate, where ACITR is ordered second in the SVAR.

Figure 5: Benchmark Impulse Responses: Min and Max States Ranked by Cumulative Responses



Notes: The top two figures show the impulse responses (solid lines), together with the 95% confidence intervals (dashed lines) of employment and GDP to a -1% shock to the average federal personal income tax rate, where APITR is ordered second in the SVAR; the bottom two figures show those to a -1% shock to the average federal corporate income tax rate, where ACITR is ordered second in the SVAR. Since the impulse responses are insignificant over the 20-quarter horizon for more than half of the states, we report only the minimum and maximum responding states, ranked by the cumulative impulse responses where–unlike the previous graph–insignificant ones are replaced by 0.

Figure 6: Cumulative Response by State (sorted by capital share)

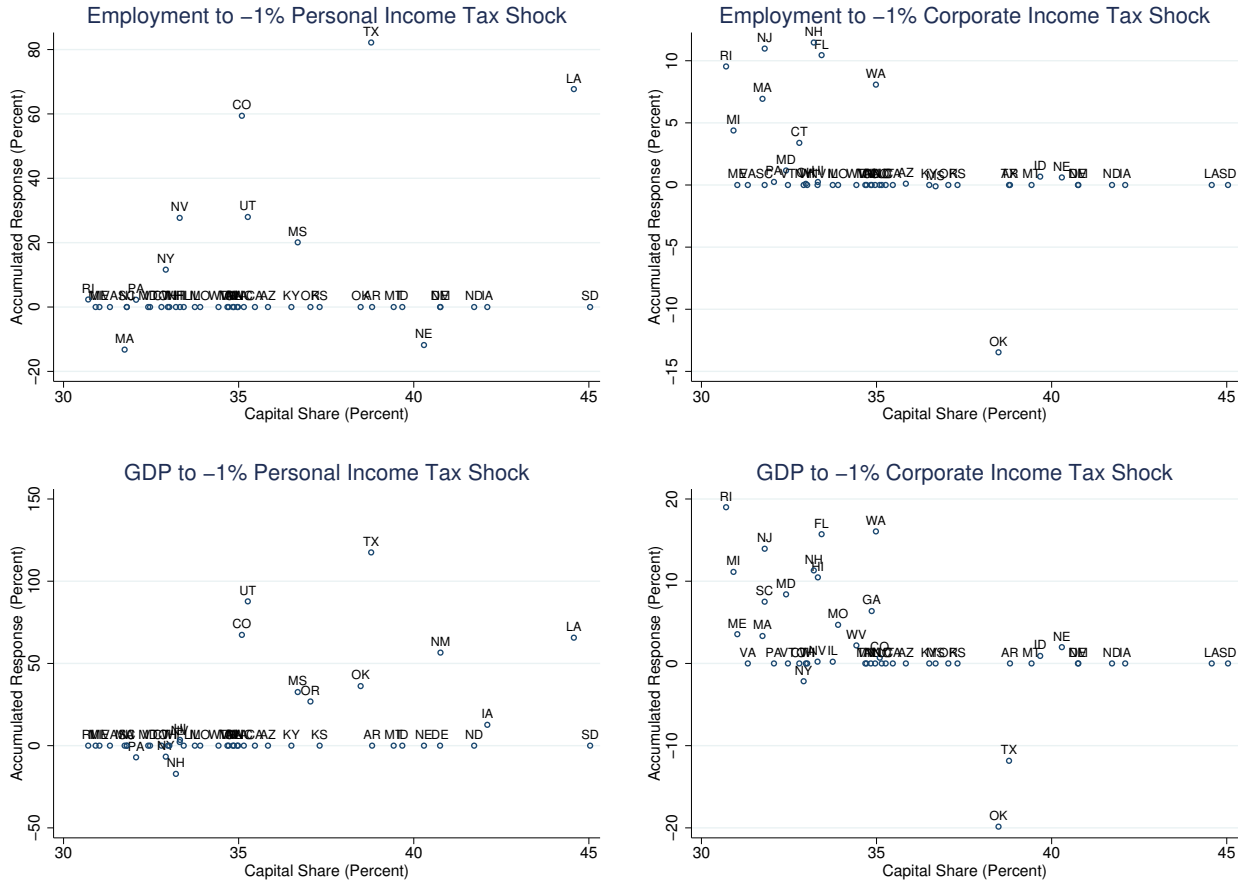


Figure 7: Corporate Sector Size vs Capital Share

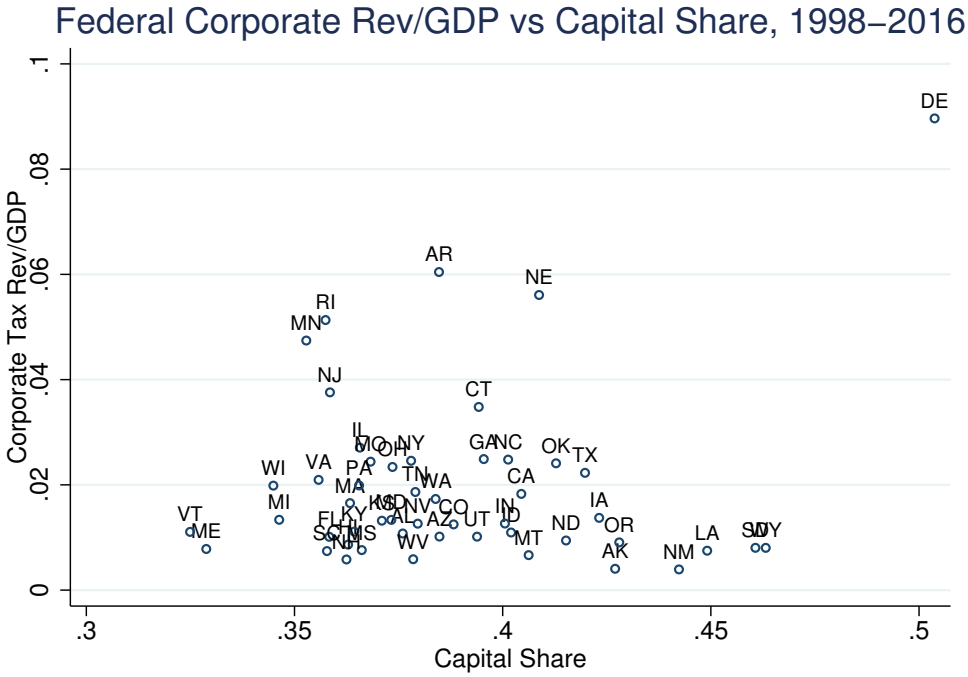


Table 3: Cumulative Responses on State Characteristics

	Panel A: All States				Panel B: Benchmark				Panel C: Using Tax Ratios			
	EMP-PIT	GDP-PIT	EMP-CIT	GDP-CIT	EMP-PIT	GDP-PIT	EMP-CIT	GDP-CI	EMP-PIT	GDP-PIT	EMP-CIT	GDP-CI
State PITR	-1.054	-6.611	-1.625***	0.574	-1.649	3.613	-1.900***	-1.391				
	(1.501)	(8.470)	(0.580)	(1.818)	(1.826)	(3.211)	(0.569)	(0.930)				
State CITR	-1.733	-1.090	0.274	-0.329	-2.036	-3.546*	0.380*	0.188				
	(1.207)	(2.989)	(0.187)	(0.585)	(1.320)	(2.010)	(0.207)	(0.424)				
Sales TR	0.579	-4.105	-0.172	0.905	0.437	1.746	-0.347	-0.239				
	(0.973)	(5.407)	(0.302)	(1.113)	(1.024)	(1.677)	(0.260)	(0.349)				
Capital Share	0.659	3.128**	-0.476***	-0.893***	1.058	2.681**	-0.497***	-0.845***	0.573	1.914*	-0.374***	-0.696***
	(0.980)	(1.371)	(0.133)	(0.307)	(1.079)	(1.228)	(0.135)	(0.228)	(0.979)	(1.038)	(0.116)	(0.210)
PIT/T									-0.311	-0.00399	-0.104***	-0.0456
									(0.286)	(0.436)	(0.0385)	(0.0803)
CIT/T									-2.020	-3.079	0.503**	0.538
									(1.244)	(1.847)	(0.221)	(0.425)
Sales/T									-0.259	-0.124	0.0114	0.121
									(0.259)	(0.418)	(0.0516)	(0.0977)
Constant	-6.412	-57.74	20.66***	30.43**	-15.93	-76.87*	22.11***	35.18***	14.22	-35.12	13.79**	21.10*
	(37.80)	(62.87)	(5.957)	(14.98)	(37.89)	(41.56)	(5.569)	(8.674)	(43.70)	(56.28)	(5.701)	(11.11)
N	50	50	50	50	48	48	48	48	48	48	48	48
adj. R^2	0.066	0.222	0.234	0.209	0.122	0.153	0.259	0.148	0.083	0.142	0.283	0.192

standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Figure 8: Impulse response of output to a corporate tax shock in a three region model with complete markets

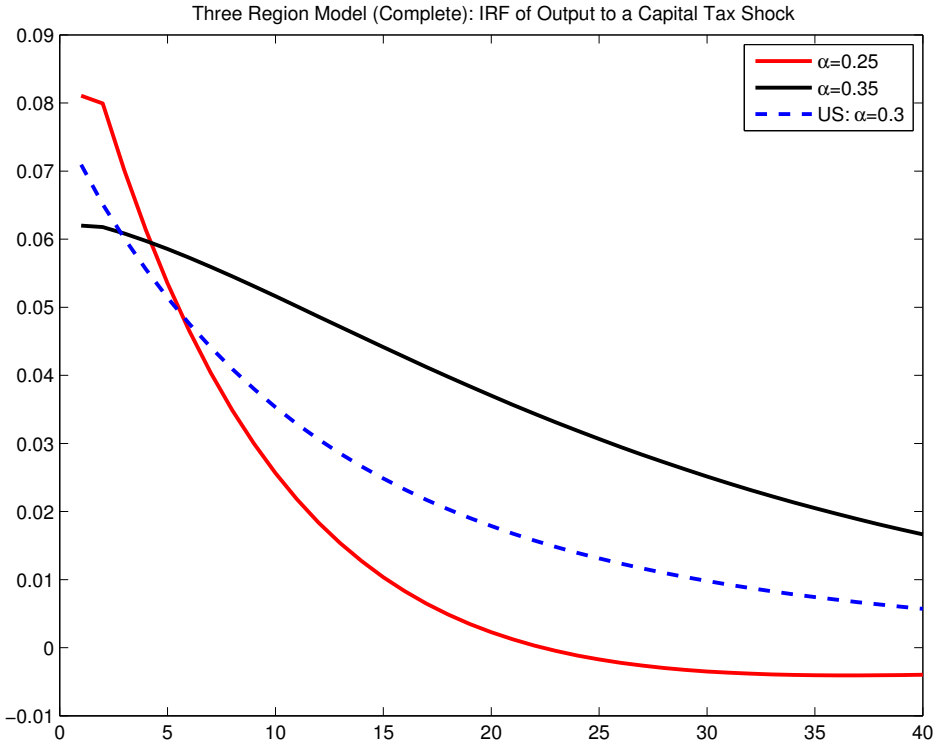


Figure 9: Impulse responses of output and employment to a corporate shock in a two sector model with incomplete markets.

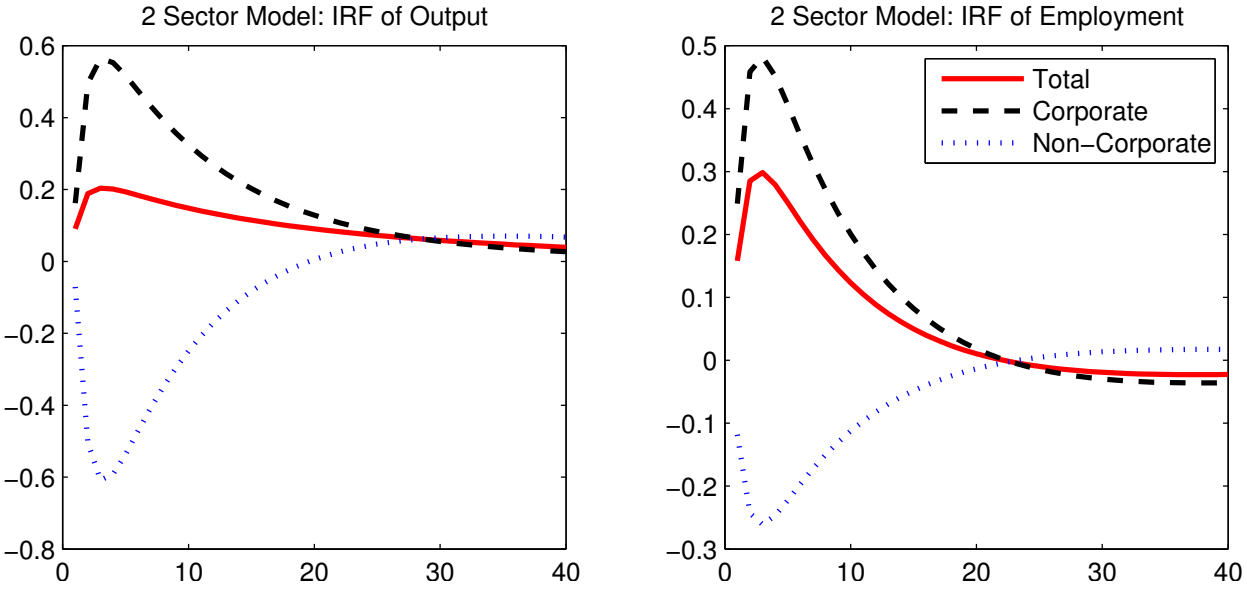


Figure 10: Impulse response and cumulative response of output to a corporate tax shock in a two sector model with incomplete markets.

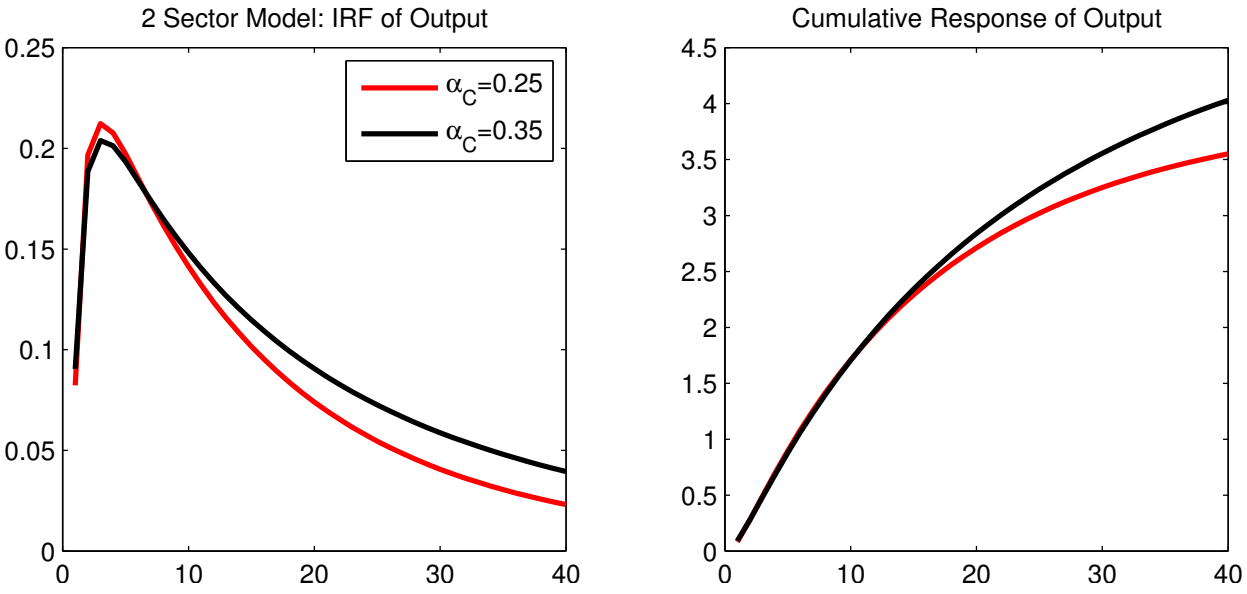
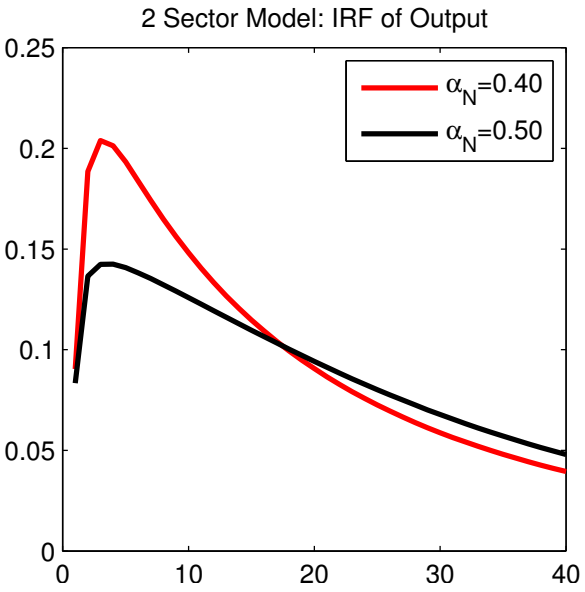
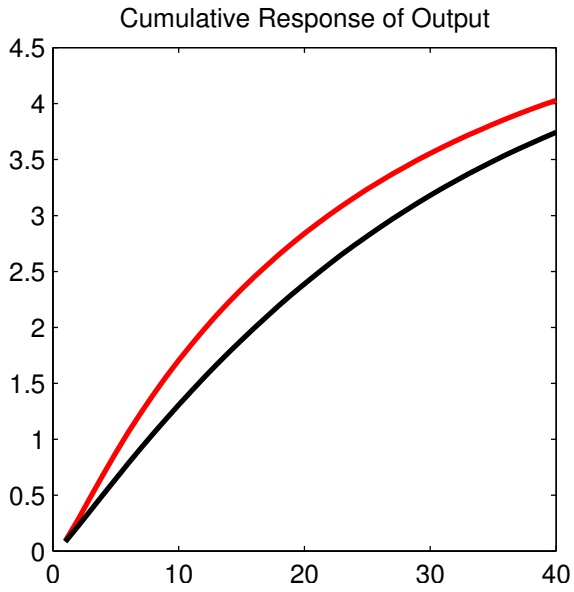


Figure 11: Impulse response and cumulative response of output to a corporate tax shock in a two sector model with incomplete markets.





Online Appendix (not for publication)

Appendix A Data

A.1 Data Construction for the Mixed-Frequency Estimation

Output. State GDP data is available at BEA Regional Economic Accounts. Quarterly real GDP by state is not available until 2005Q1; annual real GDP data ranges from 1987 up to now; nominal GDP data spans from 1963 up to now. To construct a relatively long sample of real GDP by state, we make the following changes to the raw output data:

- Keep the recent quarterly real GDP data (2005Q1-) and annual real GDP data (1997-2004), both of which are in chained 2009 dollars and based on the 2007 North American Industry Classification System or NAICS.
- Transform the annual real GDP data from 1987 to 1997 (chained 1997 dollars, and based on the 1987 Standard Industrial Classification or SIC) such that the GDP data for 1997 is the same between the two annual datasets before and after 1997.
- Apply a national GDP deflator [5] to state nominal GDP for the years 1963-1987 (based on 1972 SIC), and adjust uniformly the "real GDP" between 1963-1987 such that 1987 real output is the same with the that of the previous step to control for the impact of change in statistical methods.

The output following the above procedures is an approximate state-level real GDP (in chained 2009 one million dollars) dataset at annual frequency during 1963-2004 and quarterly during 2005-2017.

Personal Income. We obtain personal income data from BEA Regional Accounts. Nominal personal income data at quarterly frequency is available since 1948Q1 (Alaska and Hawaii since 1950Q1). This data is already seasonally adjusted at annual rates.

Total Expenditure. We compile state total expenditure data from the Census Annual Survey of State & Local Government Finances. Historical data between 1993 and 2016 is

[5] Implicit state price deflator is unavailable until 2008.

available here, where we pick the state (excluding local) total expenditure. Data from 2012-2016 are available on the American Fact Finder too. Data in 1993-2011 are collected by reading the "State & Local Government" files. Historical data prior to 1993 is stored here.[6] This dataset spans fiscal years from 1951 to 2008. And we pick 1963-1992 and combine it with the 1993-2016 data described above.

Capital Investment. Real capital data by state, 1963-2016, from the calculation of McMurry and Williams (2018).

Price Index. For state CPI, we follow the approximation approach in Herkenhoff, Ohanian and Prescott (2018) and extend their series to 2017.

PCE. We collect state consumption expenditure from the BEA Regional Data. However, data is only available annually between 1997 and 2016 in millions of *current* dollars. We apply the state price index to this nominal consumption series and get a annual-frequency real consumption (in 2009 million dollars) dataset for each state.

Employment. Total Non-farm Employment[7] is from BLS-CES State and Metro Area Databases (link). Monthly data is available and we compute the quarterly average, in order to be consistent with the data frequency of most other variables. Raw data before 1990 is not seasonally adjusted and we apply the X-13 program of U.S. Census Bureau to the sample in this period.

Unemployment Rate. Unemployment Rate data is from the BLS Local Area Unemployment Statistics, seasonally adjusted at monthly frequency. Similarly, we compute its quarterly average. This data is available after 1976.

State Tax Collection. There are two sources that our tax collection data is based on. Quarterly tax collection 1994Q1-2017Q4 comes from Quarterly Summary of State & Local Tax Revenue (TAX link)[8]. To make up for the missing quarterly tax data before 1994, we collect annual data for 1963-1993 from Annual Survey of State Government Tax Collections (STD link). We apply the X-13 program to the quarterly series, and adjust them in annual

[6] We thank a Census EWD staff for sharing this file which was not public on the website.

[7] Total employment including the farm sector is desirable for our exercise but unfortunately unavailable.

[8] This dataset provides quarterly estimates of state and local government tax revenue at a national level, as well as detailed tax revenue data for individual states. This quarterly survey has been conducted continuously since 1962. The information contained in this survey is the most current available on a nationwide basis for government tax collections.

rate.

National Block. We obtain the S&P 500 Index from "CRISP Index File on the S&P 500". All the rest are from FRED. GDP, consumption, government expenditure, investment, and personal income data are real (in chained 2009 Dollars). All the macro series are seasonally adjusted. We convert, if needed, the high-frequency series to the quarterly frequency.

Table 4: List of National Variables from FRED

Variable Name	**FRED Name**
Gross Domestic Product	GDPC1
Government Expenditures	GCEC1
Personal Consumption Expenditures	PCECC96
Consumer Price Index	CPIAUCSL
Gross Private Domestic Investment	GPDIC1
Unemployment Rate	UNRATE
Personal Income	RPI
Total Nonfarm Payroll Employment	PAYEMS
10-year Treasury Bond Yield	GS10
Federal Funds Rate	FEDFUNDS
Moody's Seasoned BAA Corporate Bond Yield	BAA

A.2 Extending the Legislated Tax Shocks Data in Mertens and Ravn (2013)

We extend the individual and corporate income tax shock data documented in Mertens and Ravn (2013) that spans 1950-2006, following the "policy motivation" guidelines of Romer and Romer (2010). *Endogenous* tax actions are "ones taken to offset developments that would cause output growth to differ from normal". These actions include the countercyclical changes made when policymakers are forecasting a recession or responding to current or projected economic conditions; and spending-driven changes made to counteract the gov-

ernment spending, e.g. the increase in payroll taxes that accompanied the introduction of Medicare program in 1965. *Exogenous* tax changes are those "not taken to offset factors pushing growth away from normal", including: changes motivated by a belief that lower marginal tax rates will raise output in the long run; changes of tax to deal with an inherited budget deficit, that "reflects past economic conditions and budgetary decisions, not current conditions or spending changes." "If policymakers raise taxes to reduce such a deficit, this is not a change motivated by a desire to return growth to normal or to prevent abnormal growth. So it is exogenous." [9]

We also follow Mertens and Ravn (2013) that discard tax changes where implementation lag is more than 1 quarter so that all the shocks involved are unanticipated; and provide subcomponents of the legislated tax actions, i.e. individual income (II) tax shocks (including employment income tax changes) and corporate income (CI) tax shocks. From 2007 to 2017, major tax reforms are as follows:

- 2007-2008, crisis time: **Economic Stimulus Act**, and the **Emergency Economic Stabilization Act of 2008**. They are clearly endogenous policy shocks.

- 2009: **American Recovery and Reinvestment Tax Act of 2009**. Economic Report of the President (2017) says: "As the name of the Act suggests, the intention was for the bill to both generate recovery from the crisis and to be an important investment in the future of the economy." "Importantly, while the Recovery Act provided a considerable short-term boost to aggregate demand, its investments were targeted for their long-term growth potential, helping ensure that the United States climbed out of the crisis stronger than before." Since the main focus of this act is to help bring economy back to normal instead of improve the long-run growth. These are endogenous tax shocks.

- 2010: **Affordable Care Act** that passed in March 2010. The primary goal for this act is to "make affordable health insurance available to more people". Hence the majority of the tax changes in this act is related to health insurance specifically. However, there were several changes on investment income (the surtax on investment income) and

[9] Romer and Romer (2010).

payroll tax (hike in Medicare payroll tax). Since they did not take effect until 2013, we do not include them in our extended sample of narrative tax changes either.

- 2011: **The Tax Relief, Unemployment Insurance Reauthorization and Job Creation Act of 2010**. Economic Report of the President (2011) says: "Government policy has supported the recovery during 2009 and 2010, and the Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act, the compromise tax framework signed into law by the President on December 17, 2010, will help the economy in 2011." These are long-run exogenous tax shocks. Most of the tax changes in this act are simply extensions of previous tax policies. According to Romer and Romer (2010), these changes are not recorded into our sample. One exception is on "Title VI: Temporary Employee Payroll Tax Cut". We obtain the CBO estimates for Title VI, which is accrued to employment tax liability change (classified under individual income tax change in Mertens and Ravn (2013)), with an amount of -67.239 billions.

  So II tax change in 2011Q1 was -67.239 billions.

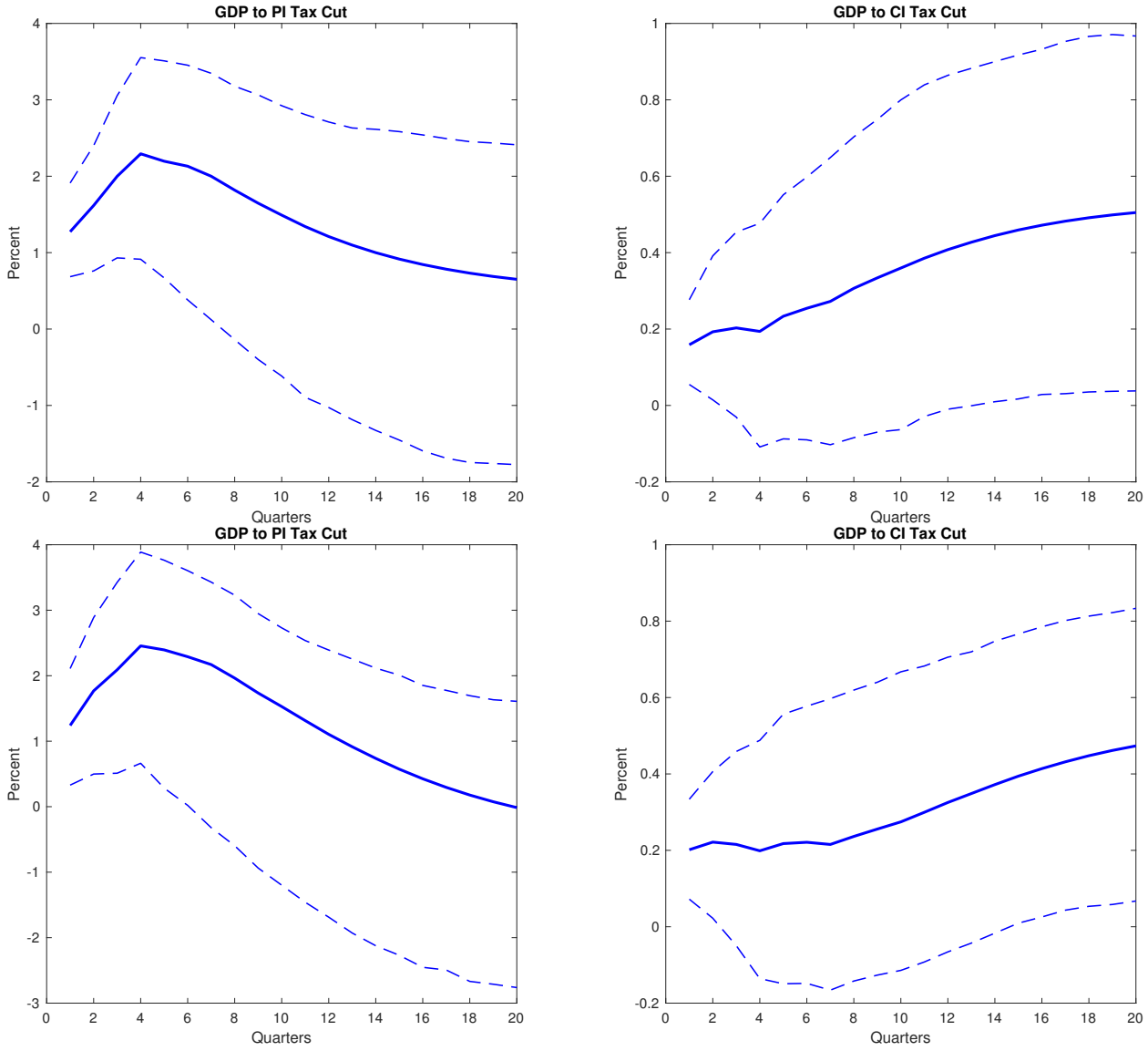
- 2013: **The American Taxpayer Relief Act of 2012** that passed on 1/1/2013. The Act centers on a partial resolution to the US fiscal cliff. So they belong to the deficit-driven exogenous tax shocks.

  II tax change in 2013Q1 was -5.901 billions; CI tax change at the same period was -63.033 billions.

- 2018: **Tax Cuts and Jobs Act, Passed Dec 2017.** Exogenous for sure, but not in our estimation time frame.

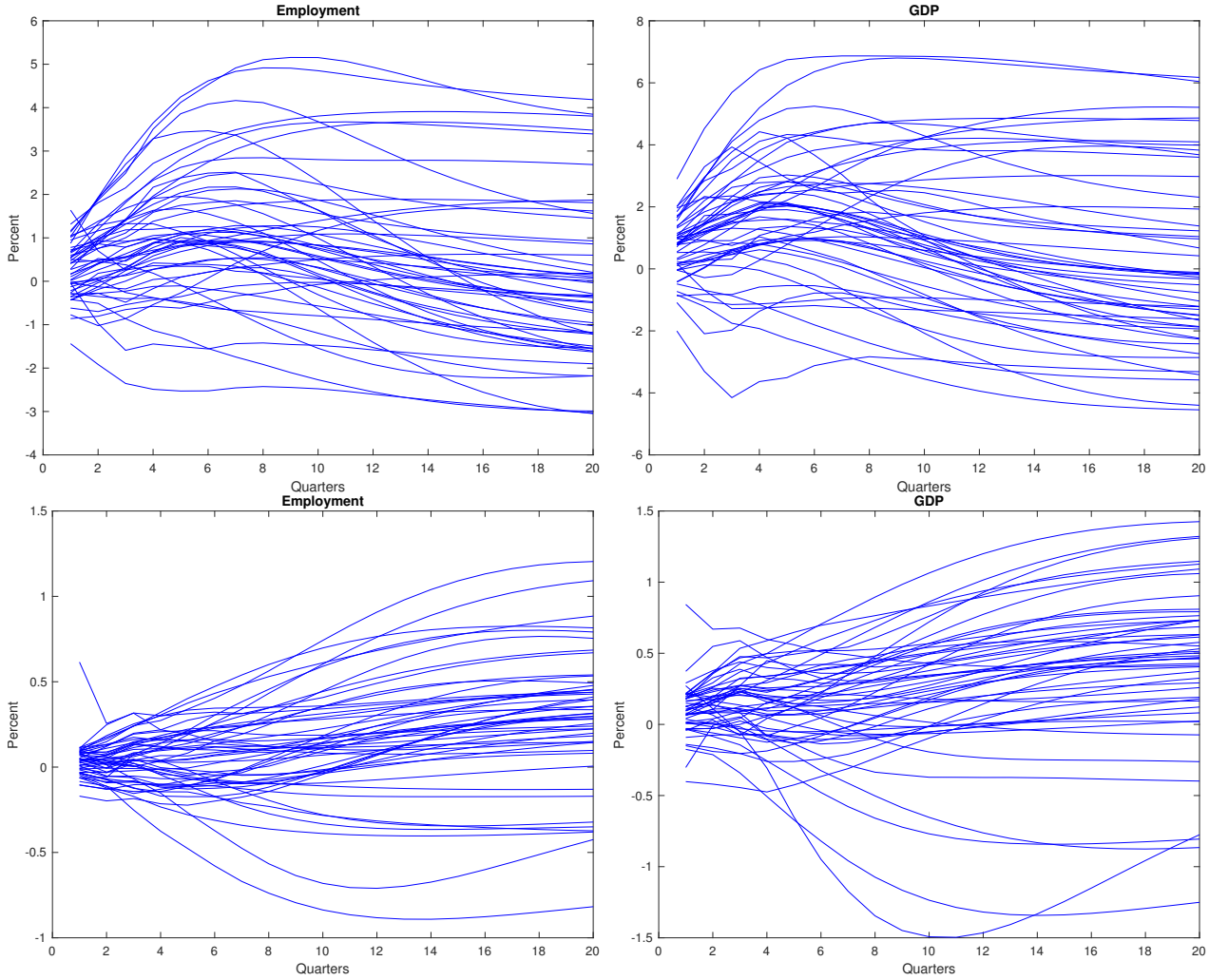
Appendix B Additional Empirical Results

Figure 12: Aggregate Impulse Responses



Notes: This figure shows the impulse responses of GDP to personal or corporate income tax cuts. The top two correspond to a SVAR with three aggregate variables: APITR, ACITR and log real GDP; and the bottom two correspond to a SVAR with five aggregate variables: APITR, ACITR, log real GDP, log real Government Expenditures, and log real Federal Government Debt. All of the macro variables are from the Mertens and Ravn (2013) data source, but not divided by total population, and with a longer sample period: 1964Q1 – 2017Q4.

Figure 13: Impulse Responses: Benchmark



Notes: The top two figures show the impulse responses of employment and GDP to a -1% shock to the average federal personal income tax rate, where APITR is ordered second in the SVAR; the bottom two figures show the impulse responses of employment and GDP to a -1% shock to the average federal corporate income tax rate, where ACITR is ordered second in the SVAR.

Table 5: Average State Tax Rates and Capital Share of Income

State Name	Individual Income Tax	Corporate Income Tax	Sales Tax	Capital Share
AL	2.18	5.48	4.00	0.35
AK	0.21	9.40	0.00	0.40
AZ	2.10	8.84	4.62	0.36
AR	2.78	6.32	4.27	0.39
CA	2.60	9.17	5.52	0.35
CO	2.31	4.97	2.99	0.35
CT	1.81	9.82	6.17	0.33
DE	3.05	8.70	0.00	0.41
FL	0.00	5.42	5.02	0.33
GA	2.81	6.00	3.51	0.35
HI	3.89	6.22	4.00	0.33
ID	3.32	7.75	4.42	0.40
IL	2.06	7.07	5.23	0.34
IN	2.18	7.73	4.64	0.35
IA	3.04	11.81	4.13	0.42
KS	2.46	7.07	4.17	0.37
KY	2.96	7.33	7.13	0.37
LA	1.70	8.00	3.43	0.45
ME	3.23	8.74	5.10	0.31
MD	2.64	7.00	4.79	0.32
MA	3.56	9.40	4.49	0.32
MI	2.70	2.51	4.79	0.31
MN	3.69	10.27	5.20	0.35
MS	1.97	4.90	5.89	0.37
MO	2.27	5.83	3.78	0.34
MT	2.70	6.68	0.00	0.39
NE	2.61	7.26	3.84	0.40
NV	0.00	0.00	5.10	0.33
NH	0.25	7.95	0.00	0.33
NJ	2.04	9.00	5.32	0.32
NM	2.11	7.67	4.38	0.41
NY	3.51	8.50	3.75	0.33
NC	3.58	6.92	3.68	0.35
ND	1.28	9.45	4.36	0.42
OH	2.37	8.00	4.74	0.33
OK	2.61	5.94	3.38	0.38
OR	4.44	6.85	0.00	0.37
PA	2.02	9.75	5.89	0.32
RI	2.50	8.97	6.13	0.31
SC	2.90	5.29	4.64	0.32
SD	0.00	0.00	3.92	0.45
TN	0.34	6.08	5.23	0.35
TX	0.00	0.00	4.95	0.39
UT	3.09	4.89	4.52	0.35
VT	2.58	8.74	4.00	0.32
VA	2.78	6.00	3.40	0.31
WA	0.00	0.00	5.76	0.35
WV	3.03	11.27	4.83	0.34
WI	3.58	7.90	4.47	0.33
WY	0.00	0.00	3.40	0.46

Figure 14: Impulse Responses to -1% Federal Personal Income Tax Rate Shock (Personal Income and Employment in SVAR)

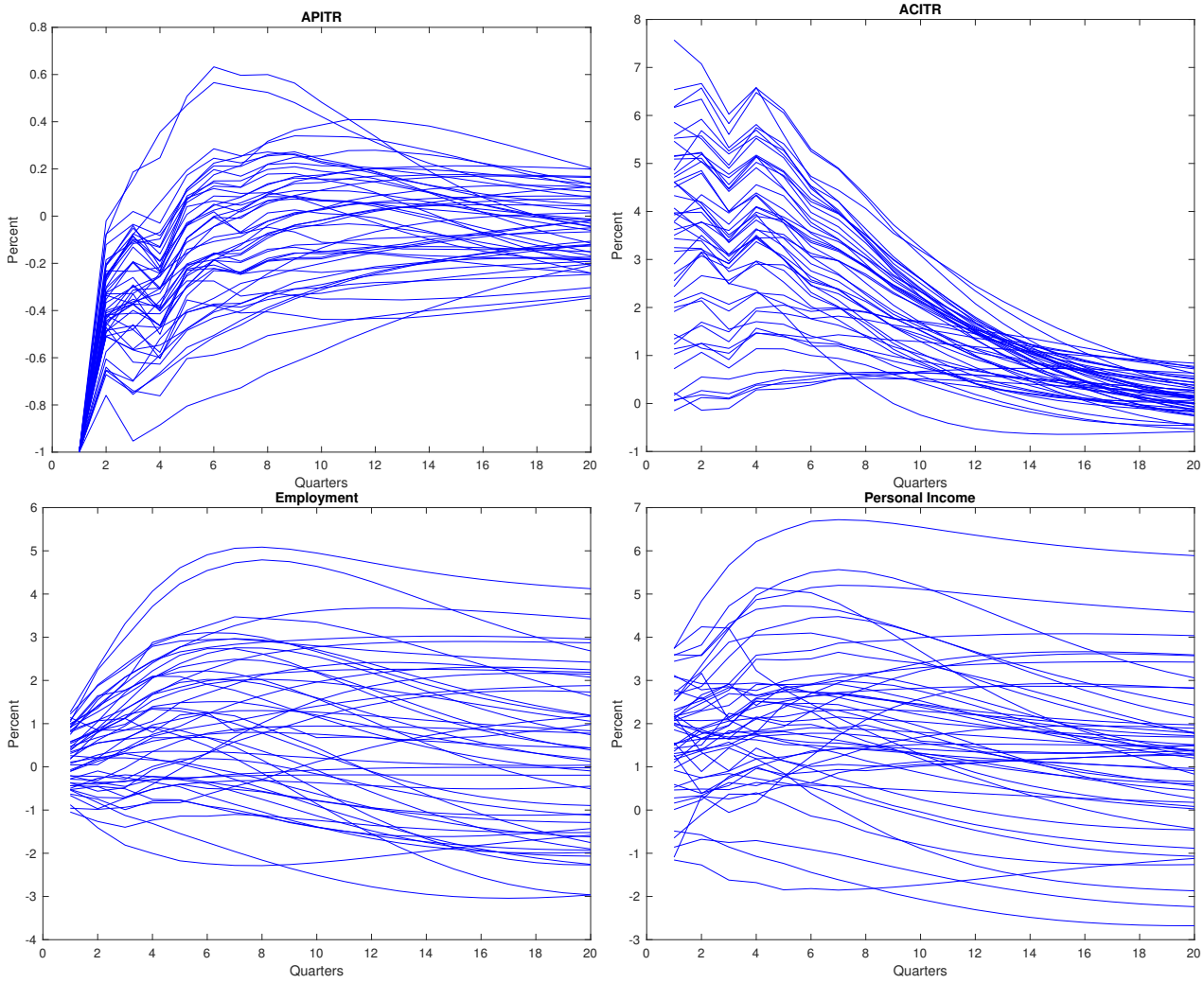


Figure 15: Impulse Responses to -1% Federal Corporate Income Tax Rate Shock (Personal Income and Employment in SVAR)

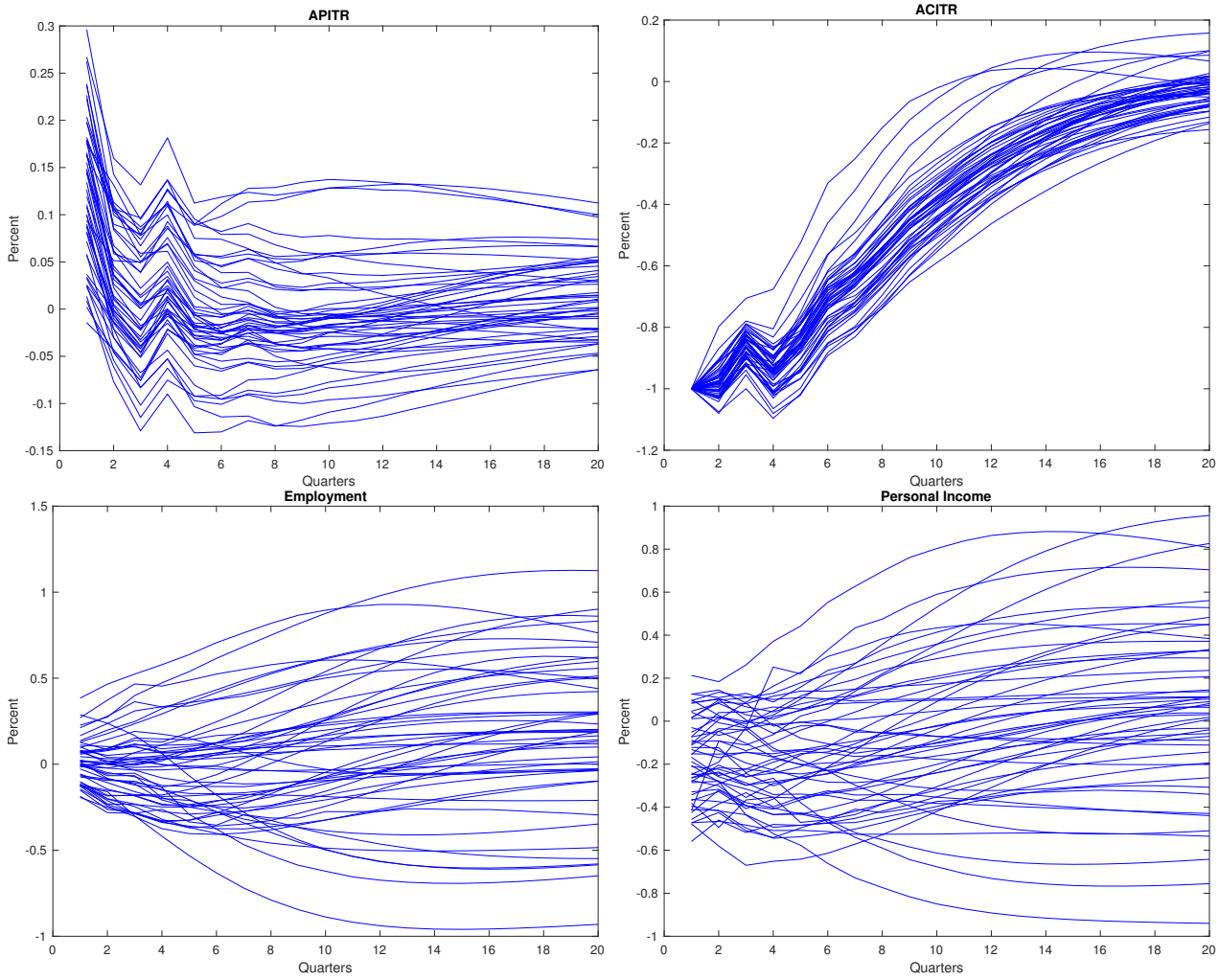


Figure 16: Cumulative Response by State (with State Government Expenditure)

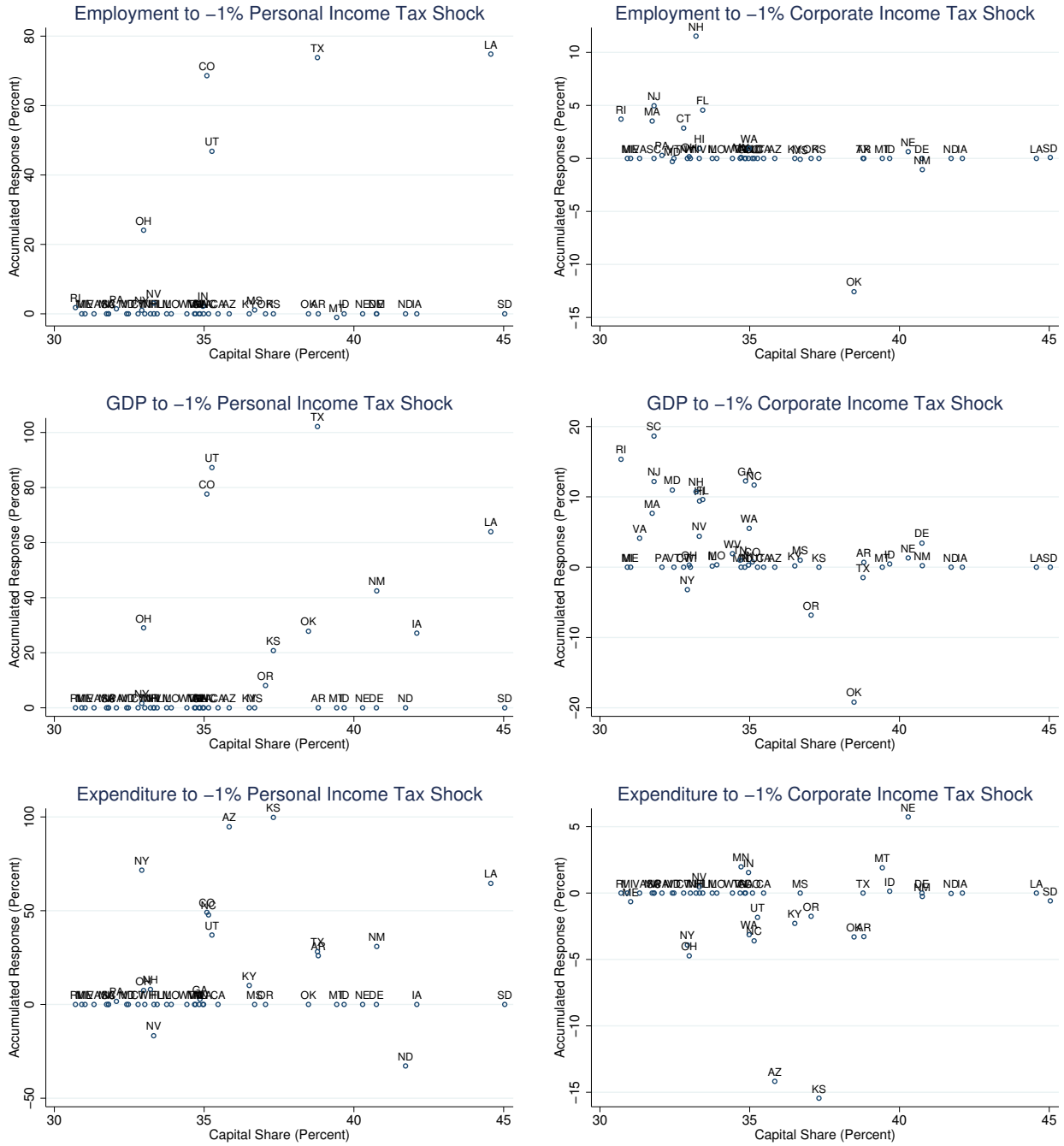


Figure 17: Cumulative Response by State (with Aggregate Variables)

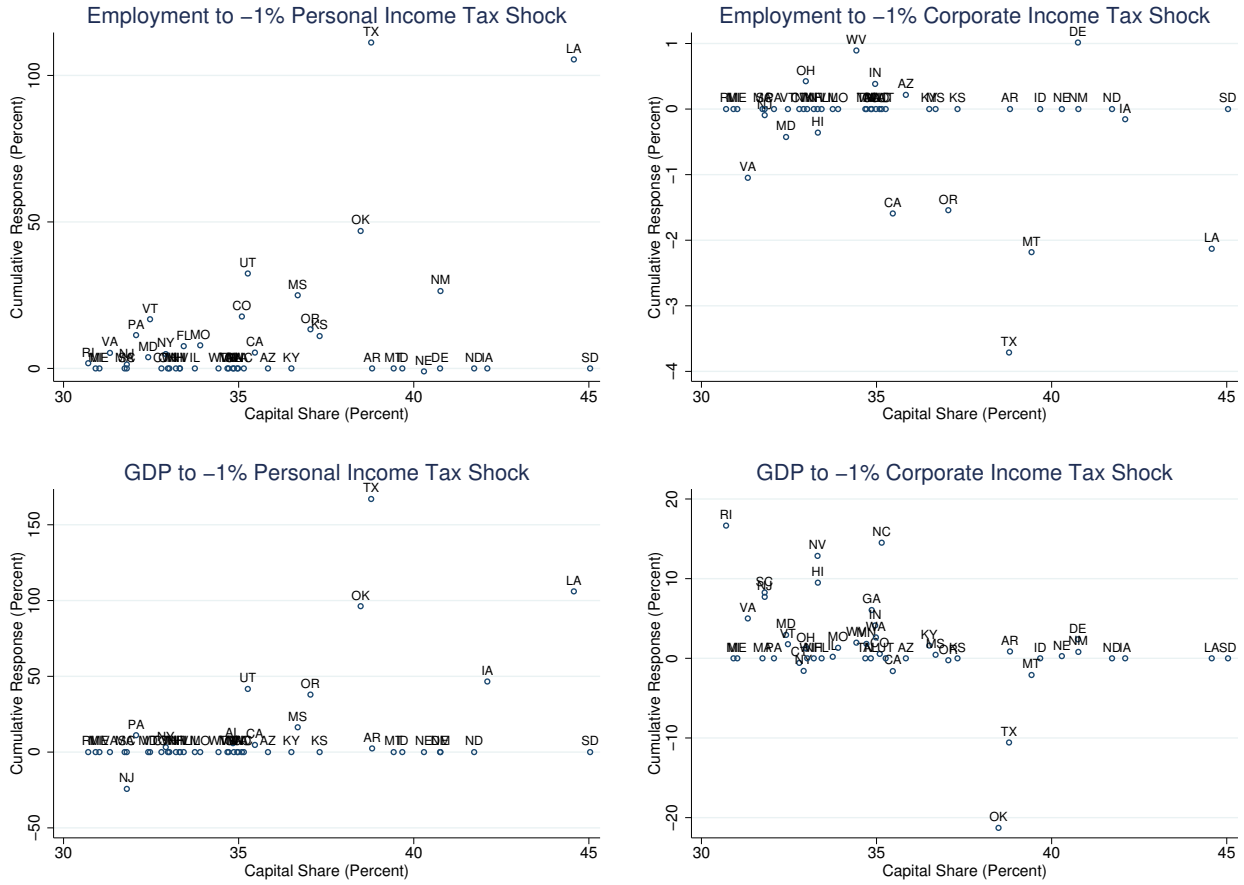


Table 6: Cumulative Responses on State Characteristics (Significance Level Not Considered)

	Panel A: All States				Panel B: Benchmark				Panel C: Using Tax Ratios			
	EMP-PIT	GDP-PIT	EMP-CIT	GDP-CIT	EMP-PIT	GDP-PIT	EMP-CIT	GDP-CI	EMP-PIT	GDP-PIT	EMP-CIT	GDP-CI
State PITR	-10.72*	-18.68	-1.551**	0.654	-4.051	1.466	-2.222***	-2.064**				
	(6.093)	(17.54)	(0.755)	(2.258)	(3.531)	(6.906)	(0.546)	(0.848)				
State CITR	-2.736	-1.152	0.284	-0.274	-3.854**	-6.297**	0.409	0.362				
	(2.249)	(5.266)	(0.275)	(0.754)	(1.716)	(2.403)	(0.256)	(0.454)				
Sales TR	-0.746	-10.51	-0.0616	1.393	2.856	1.153	-0.429	-0.155				
	(3.953)	(11.58)	(0.492)	(1.447)	(1.925)	(4.666)	(0.381)	(0.505)				
Capital Share	1.835	5.662**	-0.927***	-1.238***	1.138	5.039**	-0.867***	-1.106***	0.255	4.021**	-0.695***	-0.943***
	(1.552)	(2.724)	(0.197)	(0.390)	(1.433)	(2.003)	(0.192)	(0.292)	(1.470)	(1.833)	(0.168)	(0.264)
PIT/T									-0.546	-0.286	-0.0976*	-0.0680
									(0.358)	(0.538)	(0.0509)	(0.0825)
CIT/T									-2.618	-5.007**	0.614**	0.659
									(1.621)	(2.055)	(0.259)	(0.433)
Sales/T									0.114	-0.176	0.0643	0.153
									(0.356)	(0.576)	(0.0723)	(0.113)
Constant	-3.906	-79.82	37.78***	42.94**	-4.854	-124.8	38.17***	47.64***	30.14	-79.48	24.70***	31.91**
	(65.25)	(136.8)	(8.406)	(17.80)	(53.99)	(78.60)	(7.363)	(10.10)	(69.76)	(86.25)	(8.114)	(12.40)
N	50	50	50	50	48	48	48	48	48	48	48	48
adj. R^2	0.294	0.315	0.363	0.274	0.208	0.262	0.355	0.230	0.153	0.225	0.364	0.271

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Appendix C Additional Results for One Sector Models

Here we present and discuss the impulse responses from a variety of one sector models which we discussed in Section 3. As we discussed there, the details of the models differ but the end result is the same. In each case the structure of the model does not change the basic result that the cumulative output response to a corporate tax cut is larger with a larger capital's share of income, which is counter to our empirical results.

Figure 18 considers two parameterizations of a standard real business cycle model with government spending, proportional taxes on capital and labor, and lump sum taxes which ensure the government's budget is balanced. In particular, we consider a standard Cobb-Douglas production function (with varying α) and assume a representative household has additively separable preferences:

$$u(C, N) = \log C - \frac{N^{1+\eta}}{1+\eta}.$$

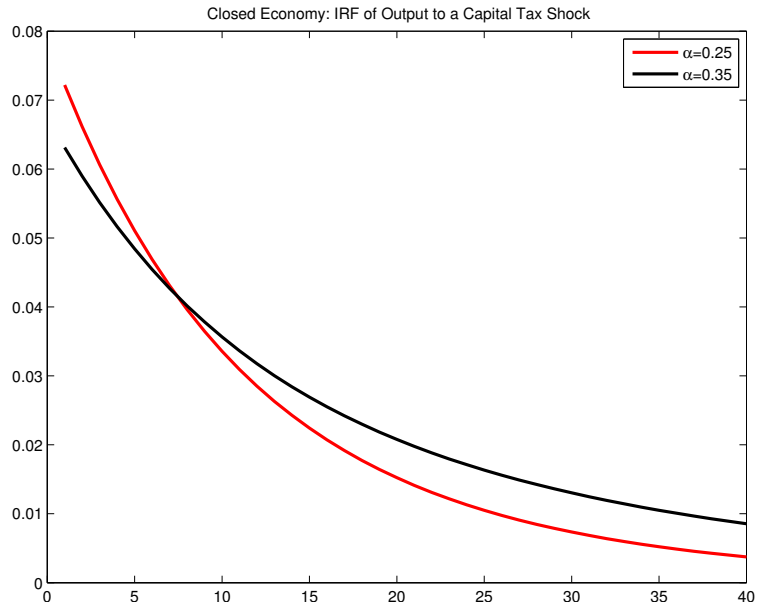
We suppose that the corporate or capital income tax is time-varying and follows the standard auto-regression:

$$\tau_{t+1} = \rho\tau_t + \varepsilon_{t+1}$$

While states are clearly not independent, closed economies, this model provides a useful benchmark. As we see in Figure 18, on impact the response of output is larger with a smaller capital's share α. This is largely due to the higher wages which accompany the tax cut and have a larger impact initially in a more labor-intensive economy. However as the capital stock grows over time, the response of the more capital intensive economy remains higher and comes to dominate. The cumulative response, which we focus on above, is thus higher with a greater capital's share.

We find much the same picture if instead of a closed economy, we suppose that each state is a small open economy. Here we focus on a case in which the state taxes national interest rates, which are determined as in a closed economy as above, as exogenous. In addition, we focus first on an incomplete markets case where capital markets are regional, with a

Figure 18: Impulse response of output to a corporate tax shock in a closed economy model

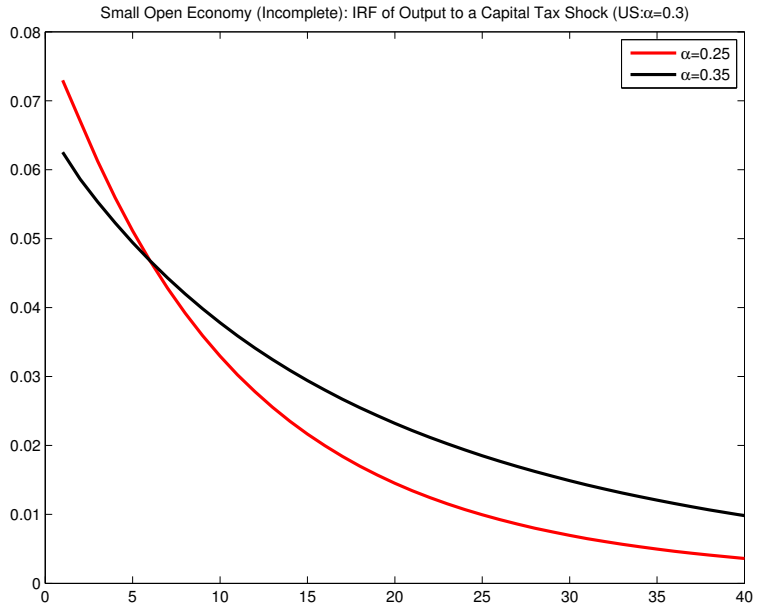


bond being the only asset traded across state borders. To make the model stationary, we follow Schmitt-Grohe and Uribe (2003) and suppose that each state has an endogenous risk premium which depends on its net external debt. In this economy, we suppose that there is a federal corporate tax shock as above, which affects the national interest rates as well as directly affecting returns on capital in the state. Figure 19 shows that the responses to a corporate tax cut are nearly identical in this economy, and thus cannot explain the impulse responses we have estimated.

In the main text we considered a regional model, where Figure 8 shows that trade and factor reallocation matter, but they suggest larger cumulative responses with more capital intensity, counter to our empirical results.

Finally, we consider a three-region variation on the model of Nakamura and Steinsson (2014), who focus on the response across US states to a government spending shock. Relative to the models discussed so far, Nakamura and Steinsson (2014) introduce nominal frictions through monopolistic competition and sticky prices. They also more explicitly model trade, as consumers in each region consume a bundle of goods from other regions, which are imperfect substitutes. In addition, although most of their paper focuses on a model without capital, they show that introducing firm-specific capital with investment adjustment costs

Figure 19: Impulse response of output to a corporate tax shock in a small open economy model with incomplete markets



preserves their main conclusions, and in particular allows them to match the regional government spending multipliers that they estimate in their empirical work. Relative to Nakamura and Steinsson, we introduce capital taxation and a third region, as in our simpler model above.

Figure 20: Impulse response of output to a corporate tax shock in a three region Nakamura-Steinsson model with complete markets

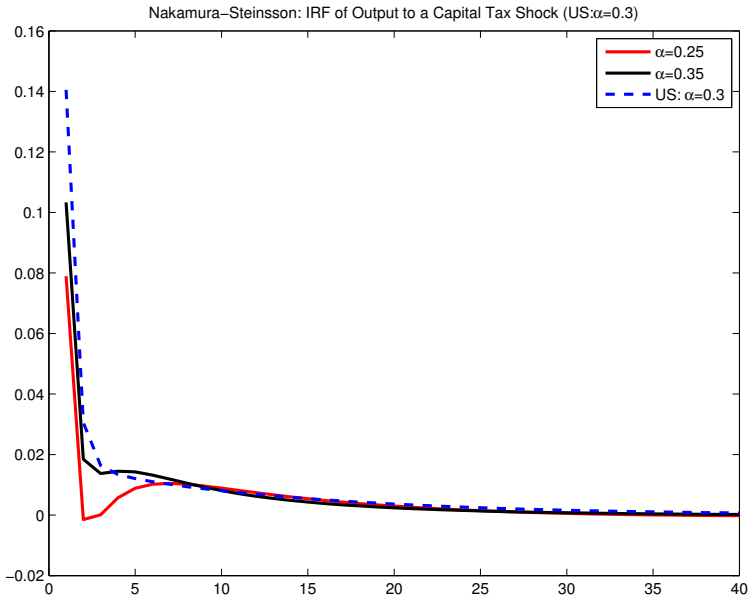


Figure 20 provides the results. Rather than prolonging the impact, the frictions in the model enhance the initial responses to the tax cut, but the effects fade away rather quickly. In addition, as in our other settings, the more capital-intensive region has a larger output response. We only show the responses for one specification of the model, which takes the baseline parameterization of Nakamura and Steinsson (2014). However the same qualitative results obtained in different parameterizations which varied the importance of the real and nominal frictions. Thus adding explicit trade and frictions do not seem sufficient to overturn the long-run implications of ours simpler models. Although this model can explain estimated government spending multipliers, it cannot (at least in this form) explain the differential responses of states to federal tax shocks that we highlighted above.