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Corporate Taxes and Vertical Tax Externalities: Evidence from Narrative Federal Tax Shocks

Yaniv Reingewertz[a]

Abstract:

The empirical aspects of vertical tax externalities have been studied fairly extensively, but with little consensus – a fact that may relate to difficulties in isolating exogenous components in tax setting policy. Adopting the case of the US and using a narrative approach (Romer and Romer 2010), I study the vertical effects of federal tax shocks. I find that vertical tax externalities are modest in their size and are only present in corporate taxation. In particular, I estimate that a $1 billion increase in federal tax revenues reduces total state corporate tax revenues by approximately $27 million. Non-corporate state tax revenues do not seem to be affected by federal tax shocks. Taking a state micro-level approach and using firm-level business activity data, I show that the findings point to the erosion of states' corporate tax bases.

JEL codes: E62, H20, H71, H77

Keywords: Vertical tax externality, narrative tax shocks, federal taxes, state taxes.

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I. Introduction

Understanding the interdependence in tax setting and tax revenues between the federal level and the state level is an important issue in the design of federal tax systems. This vertical relationship is a result of relying on similar tax bases which creates rivalry in tax collection: Changes in federal tax rates can create non-negligible effects on state budgets. Understanding these relations is important for the design of state as well as federal fiscal policy. This is the topic of this paper.

Rivalry between the federal level and the state level over the same tax base is a relatively new topic in the fiscal federalism literature. Within this body of work, most theoretical and empirical studies focus on vertical tax *competition*, meaning primarily the effects of changes in federal tax rates on state tax rates; this work has provided conflicting results. In this paper I focus on vertical tax *externalities*, namely the effect of federal tax shocks on state tax *revenues*. I isolate a plausibly exogenous component of federal tax shocks using the narrative-based methodology proposed by Romer and Romer (2010) (henceforth RR) while differentiating between corporate and non-corporate taxation.

I find that federal tax shocks are generating vertical tax externalities which are small in magnitude. More precisely, federal tax shocks moderately reduce state corporate tax revenues while having a negligible effect on non-corporate state tax revenues. Indeed, a $1 billion increase in federal tax revenues leads to a $27 million reduction in total state corporate tax revenues. These effects are statistically significant but not economically significant. I also demonstrate that the fall in tax revenue stems from reductions in the size of the tax base, using business activity data to show a negative association between federal tax shocks and the number of firms

and establishments operating in the state. Federal tax shocks do not seem to significantly affect state corporate tax rates.

In sum, I use a novel identification strategy, based on narrative reports of federal tax shocks (Romer and Romer 2010), to examine the effect of federal tax shocks on state tax revenues. In contrast to much of the literature, which tends to ignore simultaneity and endogeneity issues in tax settings, I focus on a plausibly exogenous component of federal tax changes.[1] My aim is twofold: (a) to offer a new source for vertical tax externalities, namely corporate taxation, which has been neglected in the vertical tax competition literature, and (b) to help explain the mixed results produced by studies on vertical tax competition. More precisely, I aim to address the difficulty in identifying exogenous changes to the tax code, which may be one reason for the disagreements in the literature regarding the magnitude, and even the sign, of the effect of federal taxes on state taxes.

II. Literature and Theory

a. Theory

Keen (1998) was probably the first to present a complete model of vertical tax externalities. He showed that if the federal and state levels share the same tax base, an increase in federal tax rates can erode the state tax base. In the case of unit taxes and log convexity of demand, an increase in the federal tax rate reduces state tax revenues, creating a negative vertical tax externality. If demand is not log convex then federal taxes induce a positive vertical tax externality. Dahlby and Wilson (2003) provide a similar model for the case of ad-valorem (as opposed to unit) taxes. Similarly to Keen (1998), they show that if demand is elastic, the vertical tax externality will be

[1] Devereuxet al. (2007) do address endogeneity issues and are an exception to most of the literature.

negative. However, in the case of an inelastic demand the vertical tax externality can be positive.

The results of Keen (1998) and Dahlby and Wilson (2003) could also be applied to the case where there are two (or more) tax bases and therefore two tax rates, for the federal and state levels alike. The magnitude (and sign) of the vertical tax externality will depend on the elasticity of demand in each tax base, as mentioned above. To understand the applicability of these models to our case, i.e., the US states, note that the main taxes which finance state budgets are income, corporate and sales taxes.[2] Most of these taxes are ad-valorem, and so the model of Dahlby and Wilson (2003) is more appropriate. Therefore, the sign of the vertical tax externality depends on the elasticity of demand. The demand for labor, capital and most consumer goods is likely to be elastic (see Murphy and Welch 1992, Borjas 2003 for labor demand; Papke 1991, Serrato and Zidar 2014 for capital; and Tellis 1988 for consumer goods). In other words, we would expect federal tax hikes to reduce state tax revenues due to a negative vertical tax externality. In addition, the magnitude of the externality will depend on the elasticity of demand in each of the tax bases.

A vertical tax externality exists to the extent that when federal tax rates are set, the adverse effects of these taxes on the tax base of the state level are not taken into account. The same also goes for any adverse effects of the state level on the federal tax base. However, vertical tax externalities (as well as horizontal tax externalities) can be corrected by the federal government through transfers (Dahlby 1996, Boadway and Keen 1996, Boadway et al. 1998, Hoyt 2001), or even taxes, if the federal government takes into account the effect of its tax changes on state tax revenues (Hoyt 2001).

[2] While the empirical literature provides evidence for taxes on cigarettes and fuel, I do not include these in our analysis since their contribution to state tax revenue is minute. Property taxes are usually levied at the local level, which is beyond the scope of this paper.

b) Empirics

The main contribution of this paper is to the empirical literature on vertical tax relations. I deal with the effect of federal tax shocks on state tax revenues (i.e., vertical tax externalities), analyze a plausibly exogenous channel of vertical relations, and differentiate between corporate and non-corporate taxation. The empirical literature mainly deals with vertical tax competition – i.e., the effect of federal tax rate changes on state tax rates. Evidence showing the existence of vertical tax competition can be interpreted as evidence of vertical tax externalities, in that states which increase their tax rates in the wake of federal tax rate hikes do so because the latter has caused their tax revenues to decline. However, the literature does not always deal with issues of identification and endogeneity.

To my knowledge, only two papers focus on vertical corporate tax competition: Hayashi and Boadway (2001) and Perez-Sebastian et al. (2015). Hayashi and Boadway (2001) find that provincial business income tax rates are negatively associated with federal tax rates, in Canada. Their tax rates are average effective tax rates, which are corporate tax revenues divided by corporate profits. Perez-Sebastian et al. (2015) is possibly the paper closest to this paper. They focus on tax reactions of resource-abundant states and show that these states do not suffer, and might actually benefit, from higher federal tax rates. While they focus on the case of resource-rich states and the heterogeneous effect of federal tax shocks on state tax rates, I am interested in the general (or average) effect of federal tax shocks on state tax revenues.

The empirical literature on vertical tax competition mainly deals with non-corporate state taxes, and has produced mixed results regarding the sign and

magnitude of vertical tax competition. First, dealing with excise taxes, some suggest that an increase in the federal tax rate on cigarettes and gasoline leads to an increase in state tax rates on these items (Besley and Rosen 1998, Devereux et al. 2007). However, others suggest that state cigarette tax rates *decline* when federal cigarette tax rates increase (Fredriksson and Mamun 2008). The results for gasoline taxes are also mixed: state gasoline tax revenues are adversely affected by past increases in federal gasoline tax rates, but positively affected by current tax rates (Devereux et al. 2007). The divergence in this literature stems from different samples as well as different specifications, and will be difficult to resolve without additional findings.

The empirical literature also deals with income taxes. Esteller-Moré and Solé-Ollé (2001) find a positive correlation between state and federal income tax rates. A related paper finds virtually the same result for Canada (Esteller-Moré and Solé-Ollé 2002). However, Goodspeed (2000) suggests that an increase in federal tax rates reduces state tax rates in the US. Therefore, the literature seems to suggest no conclusive result regarding vertical tax competition in income taxes.

Vertical tax competition may also prevail at the sub-national level. For example, Brett and Pinkse (2000) find that municipal business property tax rates are negatively correlated with provincial tax rates in Canada. Agrawal (2015a) finds similar results for the US. Burge and Rogers (2011) show that county tax rates negatively affect municipal tax revenues. Revelli (2003) estimates sub-national vertical fiscal externalities from the spending side. He finds that an increase in county spending from own sources (which he calls a tax burden, since this spending has to be financed from county taxes) reduces district spending in the UK. These result suggest that local governments might be trying to internalize the vertical tax externality, therefore reducing local tax rates. Contrary to other studies, Leprince et al. (2007) find

no vertical interactions between business tax rates of French regions and French departments.

This paper is also related to the literature on fiscal and tax multipliers. An increase in federal tax rates can have an indirect effect on state tax revenues (and hence on state tax rates) due to the tax multiplier and its effect on state tax bases. For example, an increase in federal tax rates would have a contracting effect on the economy (Romer and Romer 2010, Mertens and Ravn 2014).[3] This contraction would reduce employment and consumption at the state level, shrinking the tax base for state income and sales taxes. Therefore, vertical tax externalities may have macroeconomic implications.

This paper also contributes to the literature on corporate taxation and its effect on economic activity. This vast literature documents how changes in corporate taxation shift production, capital, income and profits between and within countries (see, for example, Hall and Jorgensen 1967, Harris 1993, Devereux and Griffith 1998).[4] Contemporary studies, using more sophisticated empirical models, show a similar picture. For example, Serrato and Zidar (2014) estimate the effect of corporate tax changes at the county level in the US. They show that a 1% tax cut leads to an increase of 3-4% in establishment growth. Giroud and Rauh (2015) provide similar results using state-level tax changes. Aus dem Moore (2014) finds that corporate taxes adversely affect investment activity by Belgian firms. Fossen and Steiner (2014) find an adverse effect of corporate taxes on business activity at the municipal level. Mertens and Ravn (2013, 2014), in a macro-level analysis, find a negative effect of corporate and non-corporate tax shocks on economic activity. However, Yagan (2015) provides results which are not consistent with this literature. He estimates the effect of

[3] See also Ramey (2011) for a literature review on fiscal multipliers, which also covers issues related to tax multipliers.

[4] See Deveroux and Maffini (2007) for a survey of this literature.

one corporate tax shock – the 2003 dividend tax cuts – on economic activity, and finds virtually no effect.

Last, an issue related to the vertical tax externality is the horizontal tax externality: the possibility that a lower tax rate in a state will reduce neighboring states' tax revenues.[5] While this effect has theoretical foundations (Bucovetsky 1991, Kanbur and Keen 1993), the empirical literature, dealing mostly with the local level, is highly divided. Some suggest that horizontal tax competition exists (Heyndels and Vuchelen 1998, Feld and Kirchgässner 2001, Büttner 2003, Eugster and Parchet 2013, Liu and Martinez- Vazquez 2014, Agrawal 2015b, Burge and Rogers 2016), while others offer opposing results (Lyytikäinen 2012, Baskaran 2014, Isen 2014). Devereux et al. (2007) explore state excise taxes and do find evidence for horizontal tax competition.

III. Data

I use the federal tax changes identified by Romer and Romer (2010) from the narrative record for the period 1945–2007, and assess their effect on state tax revenue as well as other state-level data.[6] Following RR, I define changes to the federal tax code as exogenous or endogenous federal tax shocks, defined as projected changes in federal tax revenues as a result of changes in the tax code. I aggregate the RR tax shocks from quarterly to annual frequency and (with the exception of Table 1) use only the exogenous tax shocks, which total about -$2.29 billion per year (Appendix A,

[5] See a broader discussion of horizontal tax externalities in Reingewertz (2014). For papers dealing with the relations between horizontal and vertical tax externalities see Keen and Kotsogiannis (2002, 2004) and Brülhart and Jametti (2006). Brueckner (2003) provides a literature review dealing with the empirical implications of these strategic interactions.

[6] Other papers which use the Romer and Romer methodology to study state-level economic activity include Zidar (2015) and Hayo and Uhl (2015), which use this measure to study economic activity, and Perez-Sebastian et al. (2015) which focus on resource-abundant states and analyze heterogeneous effects of the RR tax shocks.

Table 1). For context, federal tax shocks during this period, including both exogenous and endogenous shocks, range from a cut of $126.4 billion (in 2003) to a hike of $68.1 billion (in 2005).[7]

Romer and Romer decompose changes to the tax code to four categories – spending-driven tax changes, countercyclical tax changes, deficit-driven tax changes, and long-run growth tax changes. They define the first two categories as endogenous, since in both the tax change is considered a response to macroeconomic activity (i.e., the tax change is designed to offset short-term macroeconomic shocks). The last two categories – deficit-driven and long-run growth tax changes – are considered exogenous, because they are motivated by long-run considerations: to reduce an inherited deficit in the first case, and to stimulate long-term growth in the second. Far from being driven by immediate economic fluctuations, these types of tax changes reflect a long view, and their underlying logic may be ideological or philosophical.

Romer and Romer provide three different versions of their federal tax shocks – (a) changes in liabilities with no retroactive component, (b) changes in liabilities with a retroactive component, and (c) a version based only on the present value of tax changes. Similarly to RR, I use the first version, which in our context is almost identical to the second, since any retroactive components are likely to relate to the same year as the tax shock. The third version is less relevant to our case, since it is unlikely that firms would react only to the present value of tax shocks. RR use two functional forms of the variables – tax shocks in billions of dollars and as a ratio to nominal GDP. I use tax shocks in billions of dollars and control for Gross State Product (GSP) in the specification (see section IV). Since I use state-level data I believe that using GSP as a control variable is more appropriate than dividing by

[7] RR assess the magnitude of each tax shock based on projections by the CBO and other government agencies. A more complete description of their methodology is provided in Romer and Romer (2009) and Romer and Romer (2010).

GDP. Nevertheless, an analysis based on a shock-to-GDP ratio yields similar results to the baseline estimates (see Table 9).

For the purpose of our analysis, I classify each of the RR tax shocks as corporate or non-corporate, based on the detailed descriptions provided by Romer and Romer (2009). For example, changes to social security are classified as non-corporate, while changes in corporate tax rates and changes in depreciation rules are classified as corporate. Appendix B provides more information regarding this classification, including the variation in corporate and non-corporate federal tax shocks over time (Figures 1a and 1b in Appendix B, respectively).

I collected data on state tax revenues from the US Census Bureau's annual survey of State Government Tax Collections, which limits the sample period to 1963–2007. I look both at total tax revenues and at their division into corporate and non-corporate taxes.[8] Data on Gross State Product is taken from the Bureau of Economic Analysis (BEA). Data on business activity is collected from the Census Bureau's Business Dynamics Statistics. Finally, I collected data on employment and earnings from the IPUMS-CPS dataset (King et al. 2010). The dataset is aggregated to the state level using the weights provided in the dataset. Descriptive statistics for the main variables are given in Appendix A Table 1, and a complete list of the data sources is provided in Appendix A Table 2.

IV. Methodology

Romer and Romer (2010) assess the effect of federal tax shocks on economic activity. Therefore, they try to isolate that component of federal tax shocks which is unaffected by current economic activity. This approach is also useful for our case,

[8] I define sales tax and individual income tax revenues, which are the majority of state tax revenues, as non-corporate state tax revenues. I exclude property taxation, which is mostly relevant at the local level, and other taxes which represent a negligible part of state tax revenues.

since the main concern in identifying the effect of federal tax shocks on state tax revenues is exactly the same as in RR – the possibility that the estimates are affected by endogeneity with respect to macroeconomic fluctuations, or more precisely, that both variables are affected by the broader economic situation. An increase in economic activity will produce an increase in tax revenues at both the federal and state levels, leading to a spurious correlation between them. The RR approach can resolve this concern by focusing on a component of federal tax shocks which is arguably exogenous to current economic activity.

Another methodological concern is that of simultaneity, i.e federal tax shocks might be influenced by state tax revenues. This concern is only relevant for the largest states, as it seems implausible that tax revenues in small states will have any effect on the federal level. While this concern might be theoretically valid, it has no empirical foundations. First, looking at the documentation provided by Romer and Romer (2009, 2010), there is no mention of state-level considerations affecting tax setting at the federal level, at least not for the tax shocks they identify as exogenous. Second, the empirical literature does not offer any evidence that state tax revenues affect federal tax shocks. Moreover, the literature, as well as my results, suggest that the vertical effect of the federal level is relatively small. It seems unlikely to expect that the state level will have a larger effect on the federal level than vice-verse. Nonetheless, this type of endogeneity remains a possibility and this approach cannot entirely rule it out.

I start the analysis with Equation 1, which is a variant of Equation 5 in Romer and Romer (2010):

$$(1)\ \Delta t_{it} = \alpha + \beta \Delta T_t + \varepsilon_{it},$$

where Δt_{it} is the first difference of log state tax revenues at time *t* in state *i*, ΔT_t is a federal tax change at time *t* and ε_{it} is the residual. The residual can be decomposed to its state and federal level components in the following way: $\varepsilon_{it} = e_{it} + u_t$. An important assumption for the analysis to hold is that the state level component of the error structure, e_{it}, does not affect federal tax policy. We can further decompose the federal tax change to its endogenous and exogenous components: $\Delta T = u_t + \omega_t$, where u_t is the same as before.[9] We can rewrite equation 1 accordingly:

$$(2)\ \Delta t_{it} = \alpha + \beta\omega_t + \varepsilon_{it},$$

where ω_t is the exogenous component of RR federal tax shocks and $\varepsilon_{it} = e_{it} + u_t$. Therefore, we assume that state-level unobserved factors, e_{it}, do not affect the exogenous component of federal tax shocks.

The main difference between equations 1 and 2 here and equation 5 in RR is that I explore the effect of federal tax shocks on tax revenues, whereas RR estimate their effect on GDP. While RR use a quarterly time series for the US, I use a yearly panel data of 50 states for the period 1963–2007.[10] This difference leads to several changes to the specification, as is evident in Equation (3):[11]

$$(3)\ \Delta t_{it} = \beta \sum_{l=1}^{3} \omega_{t-l} + \gamma \sum_{l=1}^{3} t_{it-l} + \delta \sum_{l=1}^{3} t^{J}_{it-l} + \theta \sum_{l=1}^{3} X_{it-l} + F_i + \nu_{it},$$

where Δt_{it} is the first difference of log state tax revenues per capita in state *i* at time *t*, t_{it-i} is log state tax revenues per capita at time *t-i*, ω_t is the federal tax shock at year *t*, and t^{J}_{it} represents the spatial component – the log of the weighted average of

[9] In order to simplify notation we assume that all federal-level components of the residual, namely u_t, are affecting state and federal tax policy.

[10] Data for state taxes exists from 1950, but data on GSP is only available from 1963. Romer and Romer (2010) provide data up until 2007.

[11] Moving from the national level to the state level comes at the expense of the aggregation from quarterly to annual frequency, due to data limitations at the state level.

neighboring states' tax revenue.[12] I control for spatial effects due to the possibility of horizontal tax competition. X_{it} is a vector of control variables which includes the natural logarithm of gross state product per capita and a time trend. F_i is state fixed effects and ν_{it} is the residual. While the standard approach in panel fixed-effects regressions is to cluster at the panel level (in this case the state level), I take a more conservative approach and cluster the standard errors in two-way: by state and by year.[13] This is done since the results rely on the yearly variation in the federal tax shocks. I follow RR and use lags to allow for continuous effects. Therefore, all the aforementioned explanatory variables (except for the time trend) are taken in three different lags. For example, I control for gross state product at time t-1, t-2 and t-3. The use of three yearly lags is consistent with Romer and Romer (2010), who use 12 quarterly lags.

The specifications include state fixed effects since I assume that the tax changes examined are exogenous to economic activity and to state tax revenues. GSP is added in order to control for economic fluctuations, and spatial effects are added to conform to the literature, which sometimes analyzes vertical and horizontal tax externalities simultaneously. I use a time trend because federal tax shocks are the same for all states in a given year, precluding the use of annual fixed effects. In the robustness checks I introduce quinquennial fixed effects (i.e., dummy variables for a 5-year period).

V. Results

a. Main results

[12] I follow Devereux et al. (2007) and compute an average of neighbouring states' tax revenues, weighted by population. A similar computation is made for other dependent variables.

[13] Cameron et al. (2011) suggest that this approach is more suitable than one-way clustering when there are two non-nested levels which require clustering.

Table 1 presents the results of estimating equation 3, with three lags of federal tax shocks as the main explanatory variables and log state corporate tax shocks as the dependent variable. Following RR, I focus on the accumulated effect of federal tax shocks, discussing the effect of specific lags when necessary. In order to show the importance of the identification of exogenous components of federal tax changes, Table 1 presents results using the Romer and Romer (2010) total federal tax shocks (i.e. both the endogenous and exogenous component) (column 1), endogenous federal tax shocks (column 2), and the exogenous component of federal tax shocks (column 3).

The results of column 1 provide some evidence of a negative fiscal externality: a hike in federal tax shocks seems to lower state tax revenues. The estimated coefficient equals -0.00038 and is statistically significant at the 5% level. Interpreting this coefficient as a causal effect is problematic since at least some of the federal tax shocks may be endogenous. For example, changes in the business cycle affect federal tax policy as well as state tax revenues. In order to deal with endogeneity I divide the data on federal tax shocks to an endogenous and an exogenous component, based on the classification of Romer and Romer (2010).

While the endogenous component of federal tax shocks offers little information as to the magnitude of any causal effect on vertical externalities, it is interesting to examine the direction of the bias caused by using endogenous tax data. The results of column 2 are somewhat surprising, showing a positive and statistically significant cumulative effect (a coefficient of 0.00198) as well as a strong positive effect in the first and third lags. It appears that endogenous federal tax shocks *increase* state tax revenues. A possible explanation for this result is the positive relation between the business cycle and both federal and state tax shocks: when the

economy grows, federal tax revenue rise, as well as state tax revenues, leading to a positive correlation between the two. This exercise highlights the importance of identifying the exogenous component of federal tax changes, and helps to explain the discrepancy in the estimates offered by the literature. The results of column 3 provide a coefficient of -0.00069 which is highly statistically significant. Comparing the coefficients of columns 1 and 3 we see that including the endogenous component of federal tax shocks attenuated the coefficient toward zero and reduced both its economic and statistical significance.

Table 2, which presents the main results, gives a more systematic look on the different kinds of state tax revenues, in order to explore whether federal tax shocks affect corporate and non-corporate state tax revenues differently. The estimates of columns 1-3 represent the effect of federal tax shocks on state tax revenues without controlling for economic activity and spatial tax effects. These results can be interpreted as estimating both the direct and the indirect effects. For example, federal tax shocks might affect economic activity, which in turn affects state tax revenue. We can see that federal tax shocks are adversely affecting total state tax revenues (Column 1). The effect of federal tax shocks on state corporate tax revenues, which equals -0.001, is almost an order of magnitude above the effect on non-corporate tax revenues (Columns 2 and 3, respectively). Translating the coefficient of Column 2 to dollars gives a decrease of 28 million dollars in total state corporate tax revenues after a one billion dollar increase in federal taxes, or roughly 0.56 million dollars in the average state.[14] All these results are statistically significant at conventional levels.

[14] In order to calculate the mean effect (28 million dollars), I multiplied the coefficient (- 0.001) by mean state corporate taxes per capita ($116) and then by mean state population (4.826 million), and then aggregated the result across the 50 states.

While columns 1-3 present estimates which capture both the direct and indirect effects of federal tax shocks, the direct effect of federal tax shocks on state tax revenues is more interesting. Therefore, we turn to estimating equation 3 with the full set of control variables, including spatial effects and economic activity (GSP). The results for the effect of federal tax shocks on total state tax revenues, controlling for GSP and spatial effects, are presented in column 4. While the third lag is marginally statistically significant, the accumulated effect, which is negative and equal to -0.00005, is not statistically significant at the 5% level. The effect of federal tax shocks on state corporate tax revenues remains statistically significant with an accumulated effect of -0.00097, or $27 million for every $1 billion of federal tax increase (Column 5).[15] State non-corporate tax revenues don't seem to be much affected by federal tax shocks, after controlling for economic activity and spatial effects (Column 6). Summing up these results, it seems that state corporate tax revenues are adversely affected by federal tax shocks while non-corporate tax shocks seem to respond much less, if at all.

Having established a negative effect of federal tax shocks on state corporate tax revenues, which I interpret as a causal effect, we can delve further into the reasons for this link. We start by assessing whether the reduction in state corporate tax revenues is a result of lower tax rates (Table 3). Unfortunately, data for most state corporate tax rates was not available for our full sample period. The following analysis is based on data for the highest state corporate tax rate bracket, taken from the University of Michigan World Tax Database – the only such data available for the present purpose.

[15] To reach $19.2 million, I multiplied 0.00097 by mean state corporate taxes per capita ($116) and then by mean state population (4.826 million), and then aggregated the result across the 50 states.

Table 3 shows the effect of federal tax shocks on the highest bracket of state corporate tax rates. Column 1 presents the results for total federal tax shocks, while columns 2 and 3 differentiate between corporate and non-corporate federal tax shocks, respectively. As columns 1 and 2 make clear, the effects of both total and corporate federal tax shocks on state corporate tax rates are statistically insignificant. However, federal non-corporate tax shocks seem to increase state corporate tax rates, or at least their highest bracket (column 3). Therefore, we can conclude that the decline in state corporate tax revenues is not a result of lower tax rates. If anything, we see an increase in corporate tax rates in the wake of non-corporate federal tax shocks. This result is somewhat surprising: it is not clear why state corporate tax rates should respond to non-corporate federal shocks and not to corporate shocks. However, while this effect is statistically significant, its magnitude is fairly small – a $1 billion increase in federal non-corporate taxes increases the state corporate tax rate by only 0.3 percentage points. In addition, as we will see below, the effect on state tax revenues of having a smaller tax base dominates any changes which might have occurred in state tax rates.

Table 4 shows the full decomposition of federal and state taxes to their corporate and non-corporate components. Column 1 (2) analyzes the effect of federal corporate tax shocks on state corporate (non-corporate) tax revenue. Column 3 (4) analyzes the effect of federal non-corporate tax shocks on state non-corporate (corporate) tax revenue. We can see that corporate taxes are more influential, as well as more responsive. The cumulative effect of corporate federal tax shocks on state corporate tax revenue is -0.00059, or $16.5 million (column 1).[16] The cumulative effect of non-corporate federal tax shocks on state corporate tax revenue is not

[16] 0.00059 multiplied by mean state corporate taxes per capita ($116) and then by mean state population (4.826 million), aggregated across the 50 states.

significantly different from zero, though it is still negative (column 2). Moving to state non-corporate tax revenues, the results are insignificant for both corporate and non-corporate federal tax shocks (columns 3 and 4, respectively). Summing up the baseline results, I show that federal corporate tax shocks negatively affect state corporate tax revenues, and that the magnitude of this effect is relatively small.

b. Firm-level effects of federal tax shocks

After showing some evidence that federal tax shocks do not lower state tax rates, we explore whether the reduction in state corporate tax revenues reflects a shrinkage of the state tax base (Tables 5 and 6). As proxies for the state tax base I use several indicators of business activity such as the number of establishments, number of firms, and enter and exit rates of businesses. Other proxies such as corporate earnings and corporate gross income might have been more accurate, but are not available. I use total federal tax shocks, though the results hold if only federal corporate tax shocks are used.

Columns 1 and 2 in Table 4 explore the effect of federal tax shocks on the number of establishments and firms, respectively, operating in a given state, while columns 3 and 4 present the effect on firm entrance and exit rates, respectively. Both the number of establishments and the number of firms are adversely affected by increased federal taxes, with coefficients of -0.0006 and -0.0008, respectively. This means that a $1 billion increase in federal taxes reduces the total number of establishments and firms by 330 and 379, respectively.[17] Firm entrance and exit rates show a similar picture. The negative effect of federal tax shocks on firm-level activity suggests that a reduced tax base is the reason for lower state tax revenues.

[17] The calculations of these estimates are done in the following way: multiplying the coefficient which equals to 0.00006 by 110,028 (average state establishments) and multiplying the coefficient which equals to 0.00008 by 94,776 (average state firms), and then multiplying by 50 (states).

In Table 5, I further explore the effect of federal tax shocks on firm-level activity, with the aim of shedding light on which firms are affected the most. Towards this end, I categorize establishments as small (under 10 employees) or medium to large (10 employees or more).[18] Column 1 displays the effect of federal tax shocks on small establishments. As we see, the effect is negative, and of similar magnitude to the results reported in Table 4. However, large establishments are hardly affected by federal tax shocks at all (column 2). I therefore conclude that federal tax shocks affect small businesses far more than large ones.

d. Heterogeneous effects of federal tax shocks

My main contribution is in estimating the average size of vertical tax externalities – the effect of federal tax shocks on state tax revenues. A possible extension to this homogeneous effect is to study heterogeneous effects.[19] In Table 7 we explore three such extensions, using equation (3) and using state corporate tax revenues as the outcome variable. First, we assess whether states which allow firms to deduct their federal corporate tax payments from their (state corporate) taxable income are less adversely affected by federal tax shocks. These states include Alabama, Iowa, Louisiana, Missouri, and North Dakota (Advisory Commission on Intergovernmental Relations 1995).[20]

For firms operating in these states, an increase in federal tax rates is compensated, to some extent, by the state-level deduction. Therefore, we expect these

[18] The US Small Business Administration classifies small businesses by industry, with thresholds varying between 100 and 1,500 employees. This classification is not informative for our sample since the analysis is done at the establishment level and not the firm level. The results hold if I use other thresholds for firm size.

[19] Perez-Sebastian et al. (2015) estimate a heterogeneous effect related to natural resource abundance. They find that resource-rich states are not adversely affected, and might actually benefit, by federal tax shocks.

[20] Due to data limitations, the 1995 data on states which allow corporate deduction is used as a proxy for other years.

firms to be less vulnerable to federal tax shocks – they would be less likely to close, to reduce their economic activity or to relocate as a result of a federal tax hike. This means that states which offer corporate deductions would see a lower decline in the tax base in comparison to states which do not offer corporate deductions. Therefore, their tax revenues will not suffer as much as other states. Nevertheless, these states might see a small decline in corporate tax revenues due to the deduction itself.

The results of this analysis are presented in column 1 of Table 7, where we interacted the federal tax shocks variable with a dummy for states which offer corporate deductions. We can see that the cumulative effect of federal tax shocks on state corporate tax revenues for states which *offer deductions* is not statistically different from zero. The cumulative effect for states which *do not offer corporate deductions* is equal to -0.0007 and is not much different than our baseline results. Therefore, it seems that indeed states which offer deductions are less vulnerable to federal tax shocks.

The second heterogeneous effect deals with differences in economic development, since one might expect firms in rich states to be more resilient to changes in federal taxes. We interact federal tax shocks with a dummy which takes the value of one for states which have above-median GSP. The results are presented in column 2 of Table 7, and suggest that there is no heterogeneous effect between rich and poor states: the cumulative effects for these two groups are almost the same. Therefore, we find no evidence for a heterogeneous effect between rich and poor states.

Finally, we explore whether large and small states are influenced differently by federal tax shocks. We will expect large states to be less affected by federal tax shocks if firms are less likely to leave large states as a result of the increase in

taxation, e.g. because of location preferences which might be more dominant in large states. In addition, following the literature on horizontal tax competition, we would expect large states to have an advantage over small states, due to their ability to attract capital and therefore to be less affected by federal tax shocks. We interact federal tax shocks with a dummy which takes the value of one for states which have above-median population levels. The results are presented in column 3 of Table 7, and suggest that there is a difference between large and small states: the cumulative effect for large states is roughly half that of the small states (-0.00049 compared to -0.0009, respectively). Thus, it seems that large states are less adversely affected compared to small states.

e. Robustness checks

Tables 8 and 9 offer several robustness checks for the main results. We test the baseline specification of Table 2, column 5. Starting with Table 8, Columns 1-3 examine whether the results are sensitive to the lag structure of the federal tax shocks. My baseline specification, following RR, uses three yearly lags of federal tax shocks. Here we use one, two and four lags (columns 1, 2 and 3 respectively). The results show that while federal tax shocks don't seem to influence state corporate tax shocks in the first year (column 1), they adversely affect state corporate tax revenues beginning in the second year (column 2) and up through the fourth year (column 3). The cumulative effect of federal tax shocks increases when more lags are added to the analysis.

Column 4 explores whether the results are sensitive to the estimation strategy. Specifically, we test a dynamic panel-data model which is estimated using GMM (Arellano and Bond 1991). Nickell (1981) showed that using fixed-effects models to

estimate short panels with lagged dependent variables can yield biased estimates. Since the panel is relatively long, I use the Arellano-Bond estimator only as a robustness check. Looking at the results of column 4 we can see that the cumulative effect of federal tax shocks, which is equal to -0.00132, is statistically significant, and is actually larger than that in the baseline specification.

Column 5 of Table 8 adds quinquennial (5-year) dummies to the specification instead of the time trend. There 5-year dummies are in place of annual fixed effects (unusable here because in any year, federal tax shocks are the same for all states). These nine dummies take the value of one for each 5-year period from 1963 onward (and zero otherwise). The results of column 5 show a cumulative effect of -0.00099, which is almost the same as the baseline estimate.

We move to Table 9, where column 1 introduces federal transfers as an additional control variable. An increase in federal transfers will boost state revenues, and may therefore lead to actions which will reduce tax revenues, for example by creating an incentive to lower tax rates. However, adding federal transfers as a control variable affects the results very little, either qualitatively or quantitatively.

Column 2 of Table 9 normalizes the main explanatory variable, namely the federal tax shocks, by total national population. This is done in order to take into account population growth during the sample period. The results remain statistically significant and very similar in magnitude to the baseline results. Interpreting the coefficient in dollar terms suggests that increasing federal taxes by $1 per capita reduces overall states' corporate tax revenues by 4.75 million dollars. This effect is comparable to an effect of 25.5 million dollars per a federal tax shock of one billion dollars, using mean national population of 186 million (over the sample period). In column 3 we perform a similar exercise, and divide federal tax shocks by GDP. The

results are similar to the baseline results, though the interpretation of the coefficient is different due to the division by GDP. In column 4 we cluster the standard errors by year and not by state and year. This is done since the residuals might have a time-specific component which is common to all observations of the same year. The results remain statistically significant, though at the 5% level instead of the 1% level. Finally, column 5 verifies that taking the first difference of the dependent variable does not create some kind of bias in the results. The results are almost similar to the baseline results of Table 3 (column 5).

VI. Conclusion

This paper provides evidence for the magnitude of vertical tax externalities – that is, the influence of federal tax shocks on state tax revenues. I show that vertical tax externalities are present in corporate taxation, while non-corporate taxation does not seem to generate vertical tax externalities. My estimates suggest that a $1 billion increase in federal taxes leads to a $27 million decline in total state corporate tax revenues, or roughly 0.5 million dollars in the average state. I further explore the effect of federal tax shocks by looking at business activity. I show that federal tax shocks reduce firm activity. Finally, I estimate a heterogeneous effect and show that states which offer deductions for federal corporate taxation are not adversely affected by federal tax shocks, and that small states are affected more than large states.

The results suggest that corporate taxes create vertical tax externalities: state corporate tax revenues diminish when federal corporate taxes rise. This vertical tax externality is small in magnitude: a 10 billion dollar vertical shock (roughly the sample average) creates only 270 million dollars of externality (roughly 5.4 million dollars for each state), less than 2%. This effect is even smaller if I compare it to state

corporate tax revenues: the average state collects roughly 560 million dollars of corporate tax revenues per year, while the average externality amounts to 5.4 million dollars, less than 1%. The small economic magnitude of the estimates is in line with studies which suggest that vertical tax changes have no effect on state tax rates.

While the size of the vertical tax externality is fairly small, it should nevertheless be taken into account in the design of federal tax policy. The federal government should acknowledge that increasing its tax rates might adversely affect state tax revenues. Correcting this externality is possible via changes in tax rates. Alternatively, the federal government can compensate states for lost tax revenue via federal transfers. In the absence of such solutions, states have no choice but to increase their revenues some other way (e.g., by raising state tax rates) or cut state spending, even if by relatively small amounts.

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Table 1: Endogeneity of tax shocks

	All tax shocks	Endogenous tax shocks	Exogenous tax shocks
	(1)	(2)	(3)
Federal tax shocks, t-1	0.00056***	0.00109***	0.00037***
	(0.00012)	(0.00036)	(0.00013)
Federal tax shocks, t-2	-0.00058***	0.00013	-0.00058***
	(0.00013)	(0.00029)	(0.00013)
Federal tax shocks, t-3	0.00036***	0.00076***	-0.00048***
	(0.00013)	(0.00027)	(0.00014)
Cumulative effect of all federal tax shocks	-0.00038**	0.00198***	-0.00069***
	(0.00017)	(0.00060)	(0.00019)
R-squared, within	0.191	0.175	0.190
Observations	1918	1918	1918
State fixed effects	YES	YES	YES
Time trend	YES	YES	YES

Note: The dependent variable is log state corporate tax revenues per capita. Standard errors are robust, clustered by state and year, and appear in parentheses for independent variables. Superscripts *, **, *** correspond to a 10%, 5% and 1% level of significance. All regressions include state fixed effects. `Federal tax shocks' are the narrative-based federal tax shocks taken from Romer and Romer (2010). Column 1, 2 and 3 use total, endogenous and exogenous component of federal tax shocks, respectively.

Table 2: The effect of federal tax shocks on state tax revenues

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	First difference of log real state tax revenue per capita	First difference of log real state corporate tax revenue per capita	First difference of log real state non-corporate tax revenue per capita	First difference of log real state tax revenue per capita	First difference of log real state corporate tax revenue per capita	First difference of log real state non-corporate tax revenue per capita
Federal tax shocks, t-1	0.00001	0.00027**	-0.00001	0.00002	0.00027**	-0.00000
	(0.00004)	(0.00013)	(0.00004)	(0.00004)	(0.00014)	(0.00004)
Federal tax shocks, t-2	-0.00013***	-0.00075***	-0.00009***	-0.00002	-0.00068***	-0.00004
	(0.00003)	(0.00013)	(0.00003)	(0.00004)	(0.00014)	(0.00003)
Federal tax shocks, t-3	-0.00007	-0.00052***	-0.00004	-0.00005	-0.00056***	-0.00003
	(0.00004)	(0.00013)	(0.00003)	(0.00004)	(0.00014)	(0.00003)
Cumulative effect of all federal tax shocks	-0.00018***	-0.0010***	-0.00015***	-0.00005	-0.00097***	-0.00007
	(0.00006)	(0.00019)	(0.00005)	(0.00006)	(0.00019)	(0.00006)
R-squared, within	0.109	0.132	0.112	0.226	0.170	0.166
Observations	2300	2026	2300	2150	1918	2150
Spatial controls, GSP	NO	NO	NO	YES	YES	YES
State fixed effects, Time trend	YES	YES	YES	YES	YES	YES

Note: Standard errors are robust, clustered by state and year, and appear in parentheses for independent variables. Superscripts *, **, *** correspond to a 10%, 5% and 1% level of significance. All specifications include three lags of the dependent variable as control variables. The specifications presented in columns 1-3 estimate equation 3 with state fixed effects and a time trend but without the other control variables (the log of real GSP per capita, spatial effects). Columns 4-6 estimate equation 3 with the full set of control variables. All explanatory variables are taken with three different lags (t-1, t-2, t-3). `Federal tax shocks' are the narrative-based exogenous federal tax shocks taken from Romer and Romer (2010). For further information on the variables, see Appendix A.

Table 3: Tax rates

Dependent variable: Corporate tax rate	(1)	(2)	(3)
Federal tax shocks, t-1	-0.00039		
	(0.00042)		
Federal tax shocks, t-2	0.00060**		
	(0.00026)		
Federal tax shocks, t-3	0.00032		
	(0.00028)		
Cumulative effect, all federal tax shocks	0.00053		
	(0.00054)		
Federal corporate tax shocks, t-1		-0.00097*	
		(0.00052)	
Federal corporate tax shocks, t-2		0.00047**	
		(0.00024)	
Federal corporate tax shocks, t-3		0.00029	
		(0.00032)	
Cumulative effect, federal corporate tax shocks		-0.00020	
		(0.00053)	
Federal non-corporate tax shocks, t-1			0.00151**
			(0.00061)
Federal non-corporate tax shocks, t-2			0.00163*
			(0.0008)
Federal non-corporate tax shocks, t-3			0.00029
			(0.00072)
Cumulative effect, federal non-corporate tax shocks			0.00343**
			(0.00144)
R-squared, within	0.089	0.090	0.090
Observations	1686	1686	1686
States fixed effects	YES	YES	YES
Time trend	YES	YES	YES

Note: Standard errors are robust, clustered by state and year, and appear in parentheses for independent variables. Superscripts *, **, *** correspond to a 10%, 5% and 1% level of significance. All regressions estimate equation 3 with the full set of control variables (three lags of the dependent variable, the log of real GSP per capita, and the spatial controls, state fixed effects, and a time trend). `Federal tax shocks' are the narrative-based exogenous federal tax shocks taken from Romer and Romer (2010).

Table 4: The effect of federal tax shocks on state tax revenues: Corporate and non-corporate shocks

	(1)	(2)	(3)	(4)
Dependent variable:	First difference of log real state corporate tax revenue per capita	First difference of log real state non-corporate tax revenue per capita	First difference of log real state non-corporate tax revenue per capita	First difference of log real state corporate tax revenue per capita
Federal corporate tax shocks, t-1	0.00049***		0.00002	
	(0.00015)		(0.00004)	
Federal corporate tax shocks, t-2	-0.00050***		-0.00005	
	(0.00015)		(0.00004)	
Federal corporate tax shocks, t-3	-0.00057***		-0.00006*	
	(0.00014)		(0.00004)	
Federal non-corporate tax shocks, t-1		-0.00031		-0.00028**
		(0.00043)		(0.00013)
Federal non-corporate tax shocks, t-2		-0.00139***		0.00009
		(0.00044)		(0.00013)
Federal non-corporate tax shocks, t-3		0.00109**		0.00042***
		(0.00047)		(0.00013)
Cumulative effect of all federal tax shocks	-0.00059***	-0.00061	-0.00009	0.00022
	(0.00019)	(0.00066)	(0.00006)	(0.00019)
R-squared, within	0.192	0.174	0.167	0.171
Observations	1918	1918	2150	2150
State fixed effects, Time trend	YES	YES	YES	YES

Note: Standard errors are robust, clustered by state and year, and appear in parentheses for independent variables. Superscripts *, **, *** correspond to a 10%, 5% and 1% level of significance. All regressions estimate equation 3, i.e. they include as independent variables the lagged dependent variable, log of real GSP per capita, spatial effects, state fixed effects and a time trend. `Federal tax shocks' are the narrative-based exogenous federal tax shocks taken from Romer and Romer (2010), divided into their corporate and non-corporate components. For further information on the variables, see Appendix A.

Table 5: Firm-level data

	Establishments	Firms	Firm entrance rate	Firm exit rate
Dependent variable: First difference of log number of establishments	(1)	(2)	(3)	(4)
Federal tax shocks, t-1	-0.00002	-0.00004***	0.00303***	0.00496***
	(0.00001)	(0.00001)	(0.00093)	(0.00102)
Federal tax shocks, t-2	0.00001	-0.00000	-0.00068	-0.00177*
	(0.00001)	(0.00001)	(0.00101)	(0.00104)
Federal tax shocks, t-3	-0.00005***	-0.00005**	-0.00672***	0.00114
	(0.00002)	(0.00002)	(0.0009)	(0.00093)
Cumulative effect of all federal tax shocks	-0.00006***	-0.00008***	-0.00437***	0.00432***
	(0.00002)	(0.00002)	(0.00105)	(0.00129)
R-squared, within	0.130	0.134	0.474	0.513
Observations	1400	1400	1400	1400
State fixed effects	YES	YES	YES	YES
Time trend	YES	YES	YES	YES

Note: Standard errors are robust, clustered by state and year, and appear in parentheses for independent variables. Superscripts *, **, *** correspond to a 10%, 5% and 1% level of significance. All regressions estimate equation 3, i.e. they include as independent variables the lagged dependent variable, the log of real GSP per capita, spatial effects, state fixed effects and a time trend. `Federal tax shocks' are the narrative-based exogenous federal tax shocks taken from Romer and Romer (2010).

Table 6: Firm-level data: firm size

	Establishments - small firms	Establishments - large firms
Dependent variable: First difference of log number of establishments	(1)	(2)
Federal tax shocks, t-1	-0.00002*	0.00001
	(0.00001)	(0.00001)
Federal tax shocks, t-2	0.00001	0.00002**
	(0.00001)	(0.00001)
Federal tax shocks, t-3	-0.00005***	-0.00003**
	(0.00002)	(0.00001)
Cumulative effect of all federal tax shocks	-0.00006***	0.00001
	(0.00002)	(0.00002)
R-squared, within	0.102	0.420
Observations	1400	1400
State fixed effects	YES	YES
Time trend	YES	YES

Note: Standard errors are robust, clustered by state and year, and appear in parentheses for independent variables. Superscripts *, **, *** correspond to a 10%, 5% and 1% level of significance. All regressions estimate equation 3, i.e. they include as independent variables the lagged dependent variable, the log of real GSP per capita, spatial effects, state fixed effects and a time trend. `Federal tax shocks' are the narrative-based exogenous federal tax shocks taken from Romer and Romer (2010).

Table 7: Heterogeneous effects

	Deductions	GDP	Population
	(1)	(2)	(3)
Federal tax shocks, t-1	0.00032**	0.00035**	0.00051**
	(0.00014)	(0.00016)	(0.00022)
Federal tax shocks, t-2	-0.00062***	-0.00050***	-0.00086***
	(0.00014)	(0.00018)	(0.00023)
Federal tax shocks, t-3	-0.00047***	-0.00052***	-0.00056**
	(0.00014)	(0.00018)	(0.00023)
Federal tax shocks* Hetero. effect=1, t-1	0.00043	0.00004	-0.00028
	(0.00043)	(0.00027)	(0.00026)
Federal tax shocks* Hetero. effect=1, t-2	0.00039	-0.00019	0.00056**
	(0.00040)	(0.00026)	(0.00026)
Federal tax shocks* Hetero. effect=1, t-3	-0.00012	0.00009	0.00015
	(0.00037)	(0.00025)	(0.00025)
Cumulative effect: Main effect	-0.00077***	-0.00066***	-0.0009***
	(0.00019)	(0.00023)	(0.00031)
Cumulative effect: states with deductions	-0.00007		
	(0.00064)		
Cumulative effect: Rich states		-0.00073**	
		(0.0003)	
Cumulative effect: Large states			-0.00049**
			(0.00020)
R-squared, within	0.192	0.190	0.193
Observations	1918	1918	1918
State fixed effects	YES	YES	YES
Time trend	YES	YES	YES

Note: The dependent variable is log state corporate tax revenues per capita. Standard errors are robust, clustered by state and year, and appear in parentheses for independent variables. Superscripts *, **, *** correspond to a 10%, 5% and 1% level of significance. All regressions include state fixed effects, a time trend and the controls described in Equation (3). `Federal tax shocks' are the narrative-based exogenous federal tax shocks taken from Romer and Romer (2010). The interaction variables denoted by 'Federal tax shocks*Hetero. Effect=1' refer to the interaction of federal tax shocks with the dummies for a heterogeneous effect. These dummies are: states with a deduction for federal corporate taxes (column 1), states above median GDP (column2), and states with above the mean population levels (column 3).

Table 8: Robustness checks I

	1 lag	2 lags	4 lags	Arellano-Bond	5-year FE
	(1)	(2)	(3)	(4)	(5)
Federal tax shocks, t-1	0.00019	0.00026*	0.00046***	0.00003	-0.00012
	(0.00013)	(0.00013)	(0.00014)	(0.00013)	(0.00016)
Federal tax shocks, t-2		-0.00077***	-0.00067***	-0.00077***	-0.00049***
		(0.00012)	(0.00014)	(0.00015)	(0.00013)
Federal tax shocks, t-3			-0.00029**	-0.00057***	-0.00038**
			(0.00014)	(0.00012)	(0.00015)
Federal tax shocks, t-4			-0.00061***		
			(0.00014)		
Cumulative effect of all federal tax shocks	0.00019	-0.00052***	-0.00112***	-0.00132***	-0.00099***
	(0.00013)	(0.00016)	(0.00023)	(0.00016)	(0.00023)
R-squared, within	0.137	0.139	0.201		0.251
Observations	2010	1964	1872	1937	1918
State fixed effects	YES	YES	YES	YES	YES
Time trend	YES	YES	YES	YES	NO

Note: The dependent variable is log state corporate tax revenues per capita. Standard errors are robust, clustered by state and year, and appear in parentheses for independent variables. Superscripts *, **, *** correspond to a 10%, 5% and 1% level of significance. All regressions include state fixed effects. `Federal tax shocks' are the narrative-based exogenous federal tax shocks taken from Romer and Romer (2010). Columns 1 and 2 include two and four lags of the main independent variable, respectively. Column 3 uses the Arellano-Bond estimator. Column 4 introduces 5-year dummy variables to the baseline specification.

Table 9: Robustness checks II

	Federal transfers	Tax shocks/ population	Tax shocks/GDP	Clustering by year	Without first differences
	(1)	(2)	(3)	(4)	(5)
Federal tax shocks, t-1	0.00039***	0.00009**	0.00877	0.00037	0.00027**
	(0.00013)	(0.00003)	(0.01043)	(0.00023)	(0.00014)
Federal tax shocks, t-2	-0.00060***	-0.00015***	-0.06687***	-0.00058*	-0.00068***
	(0.00013)	(0.00003)	(0.01031)	(0.00031)	(0.00014)
Federal tax shocks, t-3	-0.00047***	-0.0001***	-0.02516***	-0.00048	-0.00056***
	(0.00014)	(0.00003)	(0.01064)	(0.00036)	(0.00014)
Cumulative effect of all federal tax shocks	-0.00067***	-0.00017***	-0.08326***	-0.00069**	-0.00097***
	(0.00019)	(0.00005)	(0.01638)	(0.00029)	(0.00019)
R-squared, within	0.191	0.187	0.125	0.196	0.790
Observations	1918	1918	2026	1918	1918
State fixed effects	YES	YES	YES	YES	YES
Time trend	YES	YES	YES	YES	YES

Note: The dependent variable is log state corporate tax revenues per capita. Standard errors are robust, clustered by state and year, and appear in parentheses for independent variables. Superscripts *, **, *** correspond to a 10%, 5% and 1% level of significance. All regressions include state fixed effects. `Federal tax shocks' are the narrative-based exogenous federal tax shocks taken from Romer and Romer (2010). Column 1 controls for federal transfers. In column 2 the federal tax shocks are in per capita terms (one million dollars per a population of one million). In column 3 I divide the federal tax shocks with GDP. In column 4 I cluster the standard errors by year. Finally, in column 5 the dependent variable is not in first differences.

Highlights

- The paper offers a new identification strategy to find the magnitude of the vertical tax externality.
- The findings suggest that state corporate tax revenues are affected by federal tax shocks.
- A $1 billion increase in federal tax revenues reduces total state corporate tax revenues by approximately $27 million.
- The findings suggest that the externality is a result of an erosion of state tax base and not lower states tax rates.
- State non-corporate tax revenues are not affected by federal tax shocks.

Appendix A. Summary tables

Appendix Table A1: Descriptive statistics

	N	Mean	Std. Dev.	Min.	Max.
Federal tax shocks	2250	-6.218	38.710	-148.370	75.667
Federal corporate tax shocks	2250	-10.657	37.062	-148.370	75.667
Federal non-corporate tax shocks	2250	4.438	11.325	-21.512	46.632
State tax revenues per capita (log)	2250	14.243	0.438	12.863	16.312
State corporate tax revenues per capita (log)	2010	11.494	0.705	7.581	15.36
State non-corporate tax revenues per capita (log)	2250	13.951	0.491	12.230	15.189
GSP per capita (log)	2250	17.223	0.331	16.252	18.523
Highest corporate tax rate	1948	5.854	2.983	0	12.250
Establishments per capita (log)	1550	3.093	0.141	2.735	3.566
Firms per capita (log)	1550	2.959	0.154	2.603	3.470
Establishment entry rate	1550	13.087	2.478	8.50	28.80
Establishment exit rate	1550	10.925	1.865	5.90	25.80
Small establishments (log)	1550	2.773	0.151	2.441	3.285
Large establishments (log)	1550	1.793	0.154	1.271	2.183
Unemployment	1938	0.049	0.018	0	0.170
Hours worked	1938	17.701	2.091	11.050	28.014
Log household income	1688	11.224	0.821	191	15.762

Note: The sample includes 2250 annual observations of the 50 US states, over the period 1963–2007. 'Federal tax shocks' are the narrative-based exogenous federal tax shocks taken from Romer and Romer (2010); 'corporate related' are those changes related to corporate tax, whereas 'non-corporate related' pertain to the remaining changes. 'GSP per capita' is real Gross State Product divided by state population. For further information on the variables, see Appendix Table 2.

Appendix Table A2: Data sources

Variable name	**Definition**	**Data source**
Federal tax shocks	Romer and Romer narrative federal tax shocks (in billions of dollars)	Romer and Romer (2010)
Federal corporate tax shocks	Romer and Romer narrative federal tax shocks - corporate related (in billions of dollars)	Romer and Romer (2010)
Federal non-corporate tax shocks	Romer and Romer narrative federal tax shocks - non-corporate related (in billions of dollars)	Romer and Romer (2010)
State tax revenues	Total state tax revenues per capita (log)	US Census Bureau - Annual Survey of State Government Tax Collections
State corporate tax revenues	State corporate tax revenues per capita (log)	US Census Bureau - Annual Survey of State Government Tax Collections
State non-corporate tax revenues	State non-corporate tax revenues per capita (log)	US Census Bureau - Annual Survey of State Government Tax Collections

GSP per capita	Gross state product per capita (log)	Bureau of Economic Analysis (BEA)
State corporate tax rates	Highest corporate tax rate	World tax database (University of Michigan)
Establishments	Number of establishments per capita (log)	US Census Bureau - Business Dynamics Statistics
Firms	Number of firms per capita (log)	US Census Bureau - Business Dynamics Statistics
Firm entrance rate	Firm entrance rate	US Census Bureau - Business Dynamics Statistics
Firm exit rate	Firm exit rate	US Census Bureau - Business Dynamics Statistics
Establishments - small firms	Number of establishments with less than 10 workers, per capita (log)	US Census Bureau - Business Dynamics Statistics
Establishments - large firms	Number of establishments with 10 or more workers, per capita (log)	US Census Bureau - Business Dynamics Statistics
Unemployment	Percent unemployed	IPUMS-CPS
Hours worked	Weekly working hours	IPUMS-CPS
Household income	Annual household income (log)	IPUMS-CPS

Note: All monetary variables are in real 2010 dollars.

Appendix B. Decomposing federal tax shocks

This appendix describes the decomposition of the exogenous component of the Romer and Romer federal tax shocks into corporate-related and non-corporate-related tax shocks. After aggregating the quarterly Romer and Romer data to an annual frequency, we get 27 years with changes in exogenous federal tax shocks during our sample period (1963–2007). I used the narrative record provided by Romer and Romer (2009) to classify each change based on its corporate and non-corporate components. This record summarizes the essence of each tax change and which population was affected by it.

I classified under corporate-related tax shocks any change in the federal tax code which affected corporations. These include changes in corporate tax rates, changes in incentives for investments, changes in depreciation rules, etc. I classified under non-corporate tax shocks any change in the federal tax code which affected only households. These include changes in personal income tax rates, changes in payroll taxes, and changes in medical deductions. I also assigned changes in sales

taxes and excise taxes to this group, since most of these were related to consumer goods.

While some of the tax changes outlined above occurred simultaneously, Romer and Romer provide the magnitude of most changes separately. However, sometimes the magnitude is reported for the exogenous component as a whole, without its subdivisions. In addition, in several cases Romer and Romer say that "the act reduced tax rates for all taxpayers", or some other general description. In these cases I could not classify the tax shock as corporate or non-corporate-related. To be conservative, I include these unclassified tax changes among the corporate-related tax shocks. This makes it harder to obtain precise estimates for the effect of corporate-related tax shocks on state tax revenues. The division into corporate and non-corporate tax shocks is presented in Figures 1a and 1b.

Figure 1a Federal corporate tax shocks

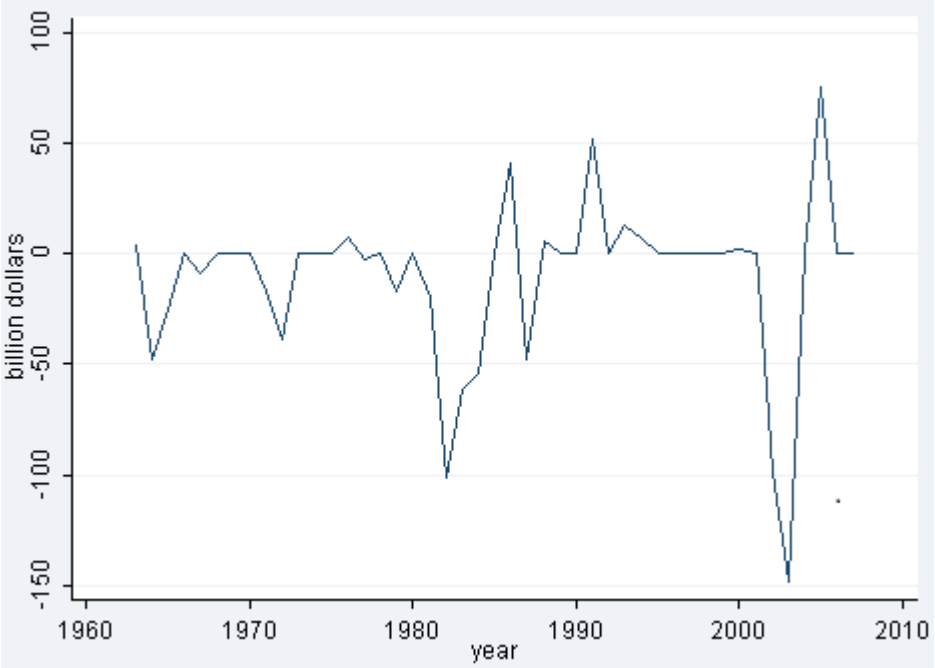
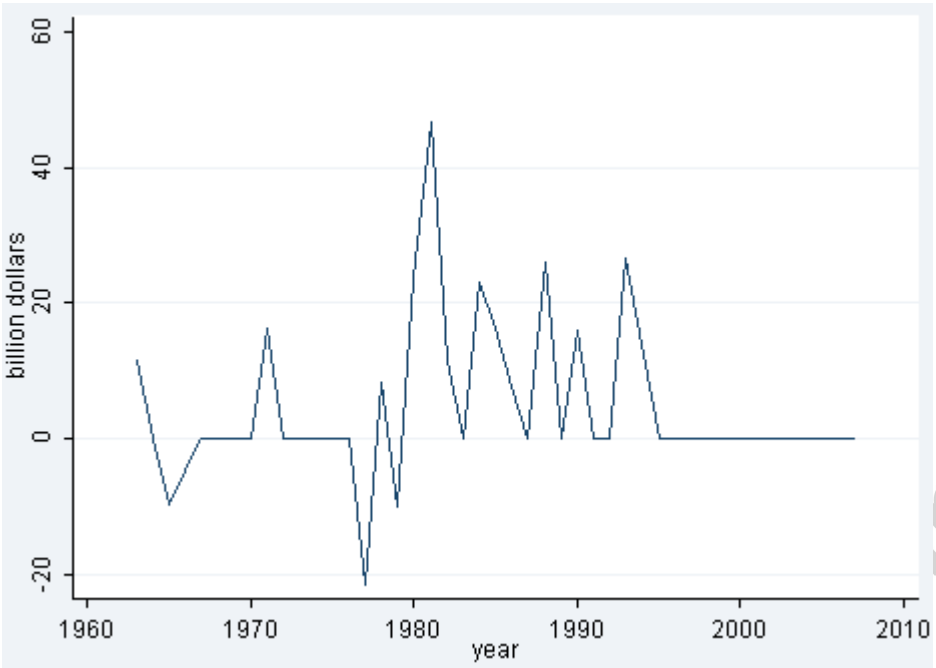


Figure 1b Federal non-corporate tax shocks



Appendix C. Household-sector effects of federal tax shocks

This appendix presents the effects of federal tax shocks on household sector activity. The results in the main text suggest that the reduced business activity following federal tax shocks would lower household income levels and increase unemployment. I use the IPUMS-CPS dataset, which includes household-level surveys of the entire US, and focus on the following variables: unemployment, hours worked, wage income and household income. The last variable, household income, is at the household level, while the others are at the respondent level. The data is aggregated to the state level using the weights provided in the survey, and compute state-level averages for each variable.

Appendix Table C.1 presents the effect of federal tax shocks on labor market outcomes and household income. First, column 1 presents the effect of federal tax shocks on unemployment. We can see that unemployment rises in the two years after

a federal tax hike but declines in the third year, so that the cumulative effect is not statistically significant. In terms of magnitude, the coefficient for the second lag, which is statistically significant, equals 0.00002, while the accumulated effect equals 0.00001. Both coefficients are small in terms of economic magnitude, suggesting that a $1 billion increase in federal taxes would lead to an increase of only 0.00002 (or 0.00001) percentage points in unemployment levels.

Column 2 tests the effect of federal tax shocks on hours worked. The results suggest an increase in hours worked, by 0.00099, though this effect is not statistically significant. Judging from columns 1 and 2, it appears that federal tax shocks push workers out of employment, while remaining workers somewhat compensate for the loss by working more hours.

Columns 3 and 4 of Appendix Table C.1 examine the effect of federal tax shocks on wages and income. We can see that wage income tends to increase after a federal tax shock, at least in the second lag, though the cumulative effect is not statistically significant (column 3). This positive association has two possible causes. First, as shown in column 2, hours worked may rise after a federal tax shock, leading to a corresponding rise in income. Second, with unemployment rising, the composition of remaining workers may change. If unemployment is concentrated in low-income workers, the average wage will increase. The results in column 4 clarify this picture by showing the effect of federal tax shocks on household income. Here we see a fall in income levels equal to -0.00006, which is roughly $4 per household. This means that while wage income might increase due to a federal tax shock, total household income declines. Note, however, that this accumulated effect is not statistically significant.

Summing up the effects of federal tax shocks on labor market outcomes, we observe an increase in unemployment, an increase in hours worked, and a possible increase in the average wage. Household income at the state level, however, declines after a federal tax shock. While estimates for the household level are fairly small and are not statistically significant, they are consistent with the results regarding state tax revenues and firm-level activity.

Appendix Table C.1: Household-sector data

	Unemployment	Hours worked	Wage income	Household income
	(1)	(2)	(3)	(4)
Federal tax shocks, t-1	0.00001*	0.00086**	0.00001	-0.00006**
	(0.00001)	(0.00041)	(0.00003)	(0.00003)
Federal tax shocks, t-2	0.00002***	-0.00185***	0.00005*	0.00009***
	(0.00001)	(0.00042)	(0.00003)	(0.00003)
Federal tax shocks, t-3	-0.00002**	0.00198***	-0.00001	-0.00009***
	(0.00001)	(0.00056)	(0.00004)	(0.00003)
Cumulative effect of all federal tax shocks	0.00001	0.00099	0.00004	-0.00006
	(0.00001)	(0.00067)	(0.00006)	(0.00005)
R-squared, within	0.154	0.148	0.117	0.119
Observations	1668	1668	1668	1514
State fixed effects	YES	YES	YES	YES
Time trend	YES	YES	YES	YES

Note: Standard errors are robust, clustered by state and year, and appear in parentheses for independent variables. Superscripts *, **, *** correspond to a 10%, 5% and 1% level of significance. All regressions estimate equation 3, i.e. they include as independent variables the lagged dependent variable, the log of real GSP per capita, spatial effects, state fixed effects and a time trend. `Federal tax shocks' are the narrative-based exogenous federal tax shocks taken from Romer and Romer (2010).