Asymmetric Effects of Tax Changes *

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Abstract

We test whether output responds symmetrically to exogenous tax increases ("positive" tax shock) and decreases ("negative" tax shock) in the postwar US quarterly data. We compute, using linear and non-linear estimation techniques, output impulse responses to positive and negative tax shocks identified using Romer and Romer (2010) data. Our results show a significant asymmetry: Output responds insignificantly to a tax increase, but shows significantly positive and permanent response to a tax decrease. We argue that these results are consistent with a ratchet effect theory where private consumption is sticky downwards. Empirical responses of macroeconomic variables to tax increases and decreases support our interpretation.

Keywords: Tax Shocks, Asymmetry Responses, Non-linear Impulse Responses, Ratchet Effect

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1. Introduction

The literature studying effects of tax changes on aggregate output, generally assumes that a tax increase (a positive tax shock) and a tax decrease (a negative tax shock) have symmetric effects on aggregate economic activity.\(^1\) In this paper, we test and reject this hypothesis of symmetric effects of a positive and a negative tax shock on aggregate levels of output. To overcome potential endogeneity concerns, we use the exogenous tax shocks as identified via a narrative approach in Romer and Romer (2010) (and measured as the change in tax liabilities as a percentage of GDP), as our tax shock measure. We divide these exogenous tax shocks based on the sign of the change in taxes (i.e., positive if the tax increases and negative if the tax decreases) and collectively refer to these tax shocks as sign dependent tax shocks. We estimate linear impulse responses by using a single equation framework in which growth rate of output is regressed on lags of sign dependent measures of tax shocks, and a three variable linear vector autoregressive (VAR) approach that includes logged output and sign dependent tax shock measures. We also estimate non-linear impulse responses by using a simplified version of the methodology presented in Kilian and Vigfusson (2011) in order to guard against the shortcomings of studying the presence of asymmetry through linear approaches. For robustness, we also redo the analysis by using changes in cyclically adjusted tax revenue as an alternative tax shock measure.

Our main finding is that a positive and a negative tax shock have an asymmetric effect on aggregate output. In particular, the estimated effect of a positive tax shock on aggregate output is insignificant while the output increases approximately by 2.5% following a negative tax shock. Additional analysis that uses changes in cyclically adjusted tax revenues instead of Romer and Romer (2010) tax shocks, show that the aforementioned results are also robust to this alternative tax shock measure.\(^2\) We further classify these Romer and Romer (2010) exogenous tax shocks into sign dependent labor (personal) income tax shocks and sign dependent corporate income tax shocks. The main result from this analysis suggests that the documented asymmetric effect of sign dependent tax shocks on aggregate output levels is mainly driven by asymmetric labor and leisure trade-offs. In particular, aggregate output increases significantly (≈ 2.5%) after a negative labor income tax shock but shows an inelastic response to a positive and a negative corporate income tax shock.

To further investigate the asymmetric effects of output levels, we extend our VAR approach to examine the responses of various other macroeconomic variables – such as total factor and labor productivity, capital, consumption, investment and total hours worked.

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\(^1\)For example, Romer and Romer (2010) (pg. 781), clearly have a symmetry in mind when they say that “... tax increases appear to have a very large, sustained, and highly significant negative impact on output. Since most of our exogenous tax changes are in fact reductions, the more intuitive way to express this results is that tax cuts have very large and persistent positive output effects.”.

\(^2\)Changes in cyclically adjusted tax revenues has been widely used in the literature as a tax measure. For example, see Giavazzi and Pagano (1990) and Alesina and Perotti (1997).
The key results show that consumption increases following a negative tax shock while it does not respond significantly to a positive tax shock. Consumers also provide more labor hours irrespective of the sign of a tax shock (more so in the case of a positive tax shock). In addition, capital and investment decrease more with a positive tax shock than they increase with a negative tax shock. In a neo-classical framework, these results provide a potential explanation of the observed asymmetric output responses to these sign dependent tax shocks.

Jointly these results can be explained through the presence of ratchet effect in consumption and labor supply. Ratchet effect in consumption, due to Duesenberry (1949), corresponds to a consumption function that accounts for habit formation and standard of living adjustments for the households. Unlike conventional frameworks where fall in income (in our case due to increase in taxes or a positive tax shock) is accompanied by a proportional fall in consumption, ratchet effect embodies household’s resistance against fall in consumption mainly due to consumption habits acquired in the past. To maintain consumption, consumers deplete their savings which has a direct effect on the quantity of capital assets consumers hold; or consumers work more which has a direct effect on the number of working hours.\(^3\)

Ratchet effect in labor supply corresponds to resistance in substituting labor for leisure following a rise in income. This could be due to commitments to the past consumption standards, risk aversion behavior of a consumer leading to accumulation of capital assets as a means of insurance, an attachment to career or additional accumulation of human capital while working and aversion to adjustment cost associated with leaving and re-entering the labor force. Employing these theories in our context with tax changes, ratchet effect in consumption resist the changes in consumption levels following a positive tax change but increases with a negative tax change and ratchet effect in labor supply resists decrease in labor supply following a negative tax change but increases due to a positive tax change.\(^4\)

Incorporating these theories into a standard neo-classical framework would then deduce that a negative tax shock would unambiguously have a positive effect on output since all the components of a neo-classical production function have a positive effect.\(^5\) However, under ratchet effect theory, labor and capital inputs behave in opposite direction following

\(^3\)Duesenberry (1949) further explained that once consumption habits are acquired, it is hard to get rid of them. He observed that earlier studies like Kuznets (1942) documented that labor saving increase with relative income whereas aggregate savings rates show no trend. He concluded that consumption is a function of previous peak level of income. When income falls, consumers try hard to maintain their consumption levels since they grow accustomed to previous level of consumption.

\(^4\)See for example, Pigou (1920), Pigou (1928) and Knight (1933) who argued that on the basis of theoretical deductions only, it is possible to show that a tax increase always leads to an increase in labor supply.

\(^5\)A negative tax shock increases individual’s income which results in an increase in consumption or saving rates but it is not accompanied by a significant decrease in the labor supply due to ratchet effect of labor supply. Incorporating these effects in a macro production function then unambiguously predicts an increase in the aggregate output.
a positive tax shock i.e., labor input increases while capital input decreases. The aggregate effect on output therefore is ambiguous and depends on how the total factor productivity (TFP) responds to a positive tax shock. If the effect on output due to changes in TFP following a positive tax shock are such that it balances off the net effect on aggregate output due to changes in capital and labor inputs (following a positive tax shock), then the aggregate effect on output can be insignificant. Impulse responses for these variables exactly reveal this offsetting effect. In addition, a combination of ratchet effect of consumption and labor supply also implies that the potential asymmetric effects of tax shocks on output level are a product of asymmetric labor and leisure trade-offs. In the event of a negative tax shock the amount of labor units replaced with leisure is smaller than the amount of leisure units replaced with labor as a result of a positive tax shock.

Methodologically, our study is similar to various studies in the literature on asymmetric effects of monetary policy such as Ravn and Sola (2004) and Cover (1992). The literature studying asymmetric effects of tax shocks is scant and primarily concentrates on state dependent effects of fiscal shocks. For example Auerbach and Gorodnichenko (2012) use regime switching models to show that tax policies and government spending policies have asymmetric effects over the business cycle. They show that fiscal policy is more effective in recessions than in expansions. Fazzari et al. (2012) also find support for asymmetric effects of government spending shocks. They, however, employ input utilization as the threshold variable in their analysis and find that when the economy has high degree of under-utilized resources, the effects of spending shocks are larger and more persistent. Hooker and Knetter (1997) utilize the state year panel data to study the response of employment growth to military spending. Their main result is that employment growth across states is explained nonlinearly by military spending. In particular, they show that a large negative shock to military spending have bigger effects on employment than the effect from a positive tax shock. Overall, the non-linearity of variables of interest documented in the existing literature is owing to state dependence of fiscal policies while our paper explores a variant of non linearity. In particular, the non-linearity in our setting is stemming from the sign dependence of tax shocks.

Numerous studies have looked at the effects of a tax shock on output without taking into

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6Three potential scenarios can be envisaged with a positive tax shock: Scenario one where the individual maintains the labor supply at the past level but runs down the capital assets accumulated in the past in an effort to maintain the current level of consumption. These effects would then entail a negative effect on aggregate output; Scenario two is where the individual maintains her capital assets but compensates her decreasing income through providing higher labor work hours. In addition, increasing work hours would also help the labor in enhancing the human capital component. Together these effects would imply that there is a positive effect on macro production followed by a positive tax shock; Scenario three where individual potentially decreases the capital asset accumulation and increases the work hour supplied and this can potentially lead to no significant effect on output. At best, the response of output to a positive tax shock is ambiguous and depends on the magnitude of the various component of production function
account the possibility of asymmetry. Additionally, there is no general consensus over the magnitude of the effect of a tax shock on aggregate output. Two seminal studies in this literature include Blanchard and Perotti (2002) and Romer and Romer (2010). Blanchard and Perotti (2002) use structural VAR and institutional information on changes in fiscal policy to estimate the fiscal policy multiplier for output as approximately 1.7. Romer and Romer (2010) use narrative records to document all post-war US legislated tax shocks and divide them into endogenous and exogenous tax shocks based on the motivation for each tax bill. They estimate a much larger elasticity of output with respect to tax changes which is around 3.8. In comparison to the estimates from these seminal studies, our estimate shows that the effect of a negative tax shock on output is somewhat in between these two documented estimates.

Rest of the paper is organized as follows: Section 2 explains in detail the sources and construction of each variable used in this paper. Section 3 describes in detail empirical specifications. Section 4 presents the baseline results of a negative and a positive tax shock on output. Section 5 provide results for the effects on output due to sign dependent labor and corporate income tax shocks in addition to the results for the effects of total sign-dependent tax shocks and separately sign dependent labor and corporate income tax shocks on other macroeconomic variables and Section 6 concludes.

2. Data

The data on tax shocks comes from Romer and Romer (2010). They study each major tax bill signed in the post-war era in the United States. They classify each tax shock as either exogenous or endogenous based on their analysis of government documents, presidential speeches and congressional documents. Tax changes in response to concerns about inherited debt or changes motivated by long term growth are classified as exogenous with respect to contemporary movements in the economy. Tax changes that were made in response to spending incidents or to bring back output to normal are classified as endogenous.9 The tax shock is then the change in the nominal tax liabilities due to these “exogenous” tax changes.

7Blanchard and Perotti (2002) explain the small multiplier through opposite effects observed for different components of output: Private consumption rises while exports and imports fall and investment crowds out due to an increase in the spending shocks.

8The strong negative response of investment due to a tax increase is used as a primary explanation for the large negative output responses in the event of a tax shock.

9The most obvious example of a tax change made in response to spending incidents would be a tax increase in the event of a war. A war causes the spending of the government to go up which is then financed by an increase in taxes. Since such a tax increase is made in response to a contemporaneous activity in the economy, it is classified as endogenous.
normalized by nominal GDP. Their study covers the period 1947Q1 to 2007Q4. Among the Romer and Romer (2010) tax shocks, we only consider exogenous tax shock measures which are legislated to be permanent. We divide these into negative tax shocks (resulting from the documented exogenous permanent tax cut or a tax decrease) and positive tax shocks (resulting from the documented exogenous and permanent tax increase). There are a total of 19 positive tax shocks and 22 negative tax shocks. The timings and the magnitude of these sign dependent tax shock measures are illustrated in Figure 1. For robustness check, we also use changes in cyclically adjusted tax revenues. The data for this tax shock measure is also taken from Romer and Romer (2010). These changes in cyclically adjusted tax revenues are quarterly and normalized by nominal GDP. Number of total positive tax shocks are 180 and total negative tax shocks are 64. The timings and the magnitude of these sign dependent tax shock measures are illustrated in Figure 2.\textsuperscript{10} Table 2 provides basic statistics for all the tax measures used in this paper.

We also use a finer break down of Romer and Romer (2010) exogenous tax shocks into labor income tax shock and corporate income tax shock. To do so, we primarily use the sources of Romer and Romer (2010), however, if the categorization into labor income and corporate income tax shock is not available in these sources, then we use other sources such as economic reports of the president and congressional budget office to categorize these accordingly. Such categorization follows the approach of Mertens and Ravn (2013a) to construct tax shock measures specific to labor income and corporate income tax shock by respectively, normalizing these changes by pretax labor income and pretax corporate profits.\textsuperscript{11} We then follow the approach in Mertens and Ravn (2013a) to construct tax shock measure specific to changes in labor income tax and corporate tax by respectively normalizing the change in these tax liabilities by pretax labor income and pretax corporate profits.\textsuperscript{12} Figure 3 and Figure 4, respectively illustrate size and sign of labor and corporate income tax shocks over the sample period of 1947Q1 – 2007Q4.

Data for other macroeconomic variables are from various sources. The data on total factor productivity (TFP) is from Fernald (2012). Fernald (2012) uses the methodology used in Basu et al. (2006) on quarterly data to estimate a TFP series from 1947Q1-2007Q4. Basu\textsuperscript{10}We also construct a de-meaned cyclically adjusted tax shock series for additional robustness check. We do not present the data and the results (which are quantitatively very similar to the results from the original cyclically adjusted tax revenues series) associated to the demeaned series to conserve space in the paper.\textsuperscript{11}For details of the methodology to identify corporate and labor income tax shocks from the Romer and Romer (2010) tax shock series, see Mertens and Ravn (2013a). In Mertens and Ravn (2013a), the personal income tax shocks are not strictly labor income tax shocks, but individual income tax shocks (i.e. it includes both labor and non-labor income tax shocks), and we use the same variable for categorization purposes. In our current paper, we use the term individual income and labor income tax shocks interchangeably. Additionally, the categorization of Mertens and Ravn (2013a) is based on taking out anticipated tax shocks from the total tax shock series while we use both anticipated and unanticipated tax shocks in our analysis.\textsuperscript{12}This is a way to put all the tax changes on a consistent basis. In this way these tax changes can roughly be considered as changes in percentage points of average tax rates.
et al. (2006) construct TFP by modifying the standard Solow residuals (output growth minus revenue-share-weighted input growth) by controlling for non-technological aggregation effects in aggregate TFP, varying utilization of capital and labor, non-constant returns and imperfect competition. The data for output, investment, and consumption is taken from Bureau of Economics Analysis (BEA). All three variables are quarterly, real and measured using chain-type quantity index. The data on labor hours, employment, and labor productivity comes from the Bureau of Labor Statistics (BLS). We use hours in non-farm business sector from the labor productivity and costs database of the BLS. For total hours, we follow Mertens and Ravn (2011) who construct the series by multiplying hours per worker and civilian non-farm employment normalized by population.

Table 1 in the appendix summarizes the data sources and time period covered for each of the variables used in this paper.

3. Empirical Specification

This paper follows linear and non-linear methodologies to test whether a positive and a negative tax shocks have asymmetric effects on output. The linear methodology combines the Romer and Romer (2010) framework with earlier works of Cover (1992) and more recently Ravn and Sola (2004) on asymmetric effects of monetary shocks, and then the linear methodology is generalized via a 3 variable vector autoregressive (VAR) approach to study the dynamic effects of a positive and a negative tax shock on output. The 3 variable VAR approach is a simplified version of specification as used in Romer and Romer (2010). We also use a simplified version of the Kilian and Vigfusson (2011) methodology to estimate non-linear impulse responses of aggregate output to a negative and a positive tax shock. Below, we explain these methodologies in detail:

3.1. Linear Approach:

As stated earlier, we combine empirical framework of Romer and Romer (2010) with the existing work on asymmetric effects of monetary shocks. In particular, let \( \tau_t \) denote the shocks to taxes at time \( t \). Define

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\tau_t^+ = \max(0, \tau_t), \quad \tau_t^- = \min(0, \tau_t)
\]

as the positive and negative shocks to the tax process, respectively. Following the literature on asymmetric effects of monetary shocks, the first step in the estimation strategy is to estimate the shock series on taxes. A simple way of doing this would be to regress nominal tax revenues (divided by nominal GDP) on contemporaneous and possibly lagged values of GDP. The errors from such a regression specification would be the shocks to taxes that are
uncorrelated with contemporaneous movements in the economy. These shocks series can then be divided into positive and negative shocks as defined in equation 1. In the second step, output is regressed on these two types of shocks to check asymmetry. This is the methodology used in Ravn and Sola (2004), Cover (1992), and DeLong and Summers (1988) and many others.

Our methodology follows Romer and Romer (2010) which provide us with exactly these uncorrelated tax shocks making the first step of estimation strategy redundant. In particular, Romer and Romer (2010) use narrative record of major tax bills in post-war US to document exogenous and endogenous tax changes. We only use the exogenous tax shocks and further split these into positive and negative tax shocks (See Section 2 for more detail). Next, we use these shocks in estimating the following equation:

\[ \Delta y_t = \alpha + \sum_{p=0}^{M} \beta^+_p \tau_{t-p}^+ + \sum_{n=0}^{M} \beta^-_n \tau_{t-n}^- + \epsilon_t \]  

where \( \Delta y_t \) is the growth rate of the chain type index for GDP and \( \tau_{t-p}^+ \) and \( \tau_{t-n}^- \) are respectively, positive and negative exogenous tax shocks (change in tax liabilities due to exogenous tax changes as a percentage of nominal GDP). The sign + and − indicates positive and negative tax shocks therefore \( \sum_{p=0}^{M} \beta^+_p \) aggregates the coefficients associated with positive tax shocks for \( M \) lags of tax shocks while \( \sum_{n=0}^{M} \beta^-_n \) denotes the aggregated coefficient associated with negative tax shocks for \( M \) lags. Following Romer and Romer (2010), we also use 12 lags for the tax shock series. Therefore, the estimates of these aggregated coefficient are the long run multipliers that capture the implied effect of a 1% tax shock (tax change normalized to GDP) on real output levels (in logarithmic form).\(^{13}\)

Equation 2 is an extension of the baseline framework used in Romer and Romer (2010). A test of symmetry would then be equivalent to testing the null hypothesis that the implied effect on output of 1 percent positive and negative tax shock is same. More formally:

\[ H_0 : \sum_{p=0}^{M} \beta^+_p = \sum_{n=0}^{M} \beta^-_n \]

We also estimate the dynamic effects of a positive and a negative tax shock on output via a 3 variable VAR. We use the VAR approach for two main reasons: (1) We believe that due to lack of theoretical basis on asymmetric effects of taxes on output, VAR provides a classical statistical model that will help us capture the statistical properties of macroeconomic time series of interest without relying too much on a particular economic theory and hence can be useful in our analysis, (2) VAR is also beneficial to account for other factors that may affect output or other variables of interest while alternative approaches do not account for

\(^{13}\)See Romer and Romer (2010) for more detail.
the missing variables and therefore can potentially result in biased conclusions. The VAR specification can be represented as:

$$X_t = A + B(L)X_{t-1} + e_t$$

where $B(L)$ is a $p$-order lag polynomial$^{14}$ and $e_t = [e^Y_t, e^\tau^+_t, e^\tau^-_t]$ is the vector of shocks. $X_t = [y_t, \tau^+_t, \tau^-_t]'$ is a $3 \times 1$ vector with quarterly observations of $y_t$, the logged output and $\tau^+_t$ and $\tau^-_t$ the tax measures described above. The key assumption in this analysis is that the changes in taxes are observable and exogenous.$^{15} \hspace{1em}^{16}$

### 3.2. Non-Linear Approach

Kilian and Vigfusson (2011) argue that, in an asymmetric model, computing impulse responses using the techniques employed in symmetric models can be misleading. Linear impulse responses are computed by assuming that a shock hits the variable of interest and then no subsequent shock hits the economy for the next several periods. In an asymmetric model, however, such an assumption can bias the results. In particular, for example, the effect of a positive tax shock on output will depend on both the history of shocks of both negative and positive tax shocks, and also on the subsequent values of the realizations of these tax shocks.

In this section, we use a simplified version of the Kilian and Vigfusson (2011) methodology to compute non-linear impulse responses to a positive and a negative tax shock.$^{17}$ Our methodology to compute non-linear impulse responses can be summarized as follows:

1. Estimate equation (2) for a particular type of tax shocks (either the Romer and Romer

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$^{14}$We again follow Romer and Romer (2010) and take the value of $p$ as 12.

$^{15}$For an alternative specification see, Mertens and Ravn (2013b). We specifically use the VAR specification 3 in order to make close comparisons to the results from Romer and Romer (2010).

$^{16}$One implication of assuming exogenous tax shocks in the VAR framework is that $\tau^+_t = e^\tau^+_t$ and $\tau^-_t = e^\tau^-_t$ because all the coefficients in $B(L)$ will be insignificant, i.e. events happening in the economy will have no effect on $\tau^+_t$ and $\tau^-_t$. Although Romer and Romer (2010) classify tax changes as either endogenous or exogenous, there still may be an element of doubt that there is some endogeneity in the “exogenous” tax changes as well. Formally, Mertens and Ravn (2011) test this assumption and find that past values of exogenous tax shocks have no predictive power for future exogenous tax changes. In contrast they find that past values of endogenous tax changes have predictive power for future tax changes.

$^{17}$In particular, computing non linear impulse responses based on the non-linear methodology proposed by Kilian and Vigfusson (2011) involves two steps. The first step estimates the shocks and the second step then utilizes these estimated shocks to compute non-linear impulse responses. In our framework, the first step is not required since we use identified shocks from the Romer and Romer (2010) tax series. First step aside, the second step that uses these shocks to estimate the non-linear responses is exactly the same as Kilian and Vigfusson (2011).
(2010) measure or the cyclically adjusted tax revenues). Collect the estimated coefficients for the equation and also the residuals $\epsilon_t$.

2. Pick a history, $\Omega^i_{t-1}$, which consists of a block of $M$ consecutive values of $\tau^+_t$ and $\tau^-_t$. These are actual values from the data series on these two variables. The values drawn for both shocks should be for the same dates.

3. Choose a sequence of $H$ negative and positive shocks from the series on these variables with replacement. Also choose a sequence of $H$ values of the residual $\epsilon_t$ with replacement from the residuals collected after the initial estimation.

4. Using the history, $\Omega^i_{t-1}$, and the sequence of shocks, simulate $H$ values of $y_t$. These values are simulated by using equation 2. Call this time path $y^{ns}_{t+j}$, $j = 1, 2, ..., H$.

5. Now repeat step 4 with one change. In the shock sequence of negative and positive taxes, replace the first value of either of the two taxes (to which the shock is to be given) by a constant value $\delta$. If the shocks is to be given to positive tax, then $\tau^+_t$ will be set equal to $\delta$. Values of all $\tau^+_t$ such that $j = 2, 3, ..., H$, estimate the time path of $y_t$ for this new sequence of shocks and call it $y^s_{t+j}$ where $j = 1, 2, ..., H$.

6. Take the difference of the two simulated paths. Repeat steps 3 through 5 $N$ number of times and collect $N$ such series. Average the resulting series to obtain the impulse response of $y_t$ to a shock size of $\delta$ conditional on history $\Omega^i_{t-1}$. This impulse response of $y_t$ can be represented as

$$ IRF(h, \delta, \Omega^i_{t-1}) = \frac{\sum_{k=1}^{N} y^s_{t}(h, \delta, \Omega^i_{t-1}, k) - y^{ns}_{t}(h, \Omega^i_{t-1}, k)}{N} $$

where $y^{ns}_{t}(h, \Omega^i_{t-1}, k)$ represents the computed value of $y_t$ from step 4 at $h^{th}$ horizon. $y^s_{t}(h, \delta, \Omega^i_{t-1}, k)$ represents the estimated value of $y_t$ from step 5 at $h^{th}$, $h = 1, 2, ..., H$ horizon after a shock of size $\delta$ for history $\Omega^i_{t-1}$ selected in step 2. $k = 1, 2, ..., N$ such values are computed through steps 4 and 5.

7. Finally, average $IRF(h, \delta, \Omega^i_{t-1})$ over all histories to obtain the non-linear impulse response of $y_t$ to a shock size of $\delta$. This impulse response can be represented as

$$ IRF(h, \delta) = \int IRF(h, \delta, \Omega^i)d\Omega^i $$

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18 Note that when impulse responses are estimated using equation (2), the value of $H$ cannot be bigger than $M$ since the effect of tax shocks only last for $M$ periods.
4. Results

We begin by documenting the effects of tax shock measures on output using linear approaches via a simple ordinary least square equation referred as a benchmark model and vector auto regression (VAR) approach in Section 4.1. The next section, Section 4.2 then documents the main results of an analogous analysis on output using the non-linear methodology.

4.1. Results: Linear Approach

Using a single equation approach as described in Section 3, we first present the results for the significance of the corresponding cumulative coefficients of a positive tax shock and a negative tax shock (see row 1 and 2 in Table 3) along with the significance of the difference between these coefficients (see row 3 in Table 3). Second, we present impulse responses in Figure 5 along with coefficients corresponding to each lag of both a positive and a negative tax shock (see column 1 and 2 of Table 4).

F tests (reported in row 1 and 2 of Table 3) show that the cumulative effect of a positive tax shock on output is insignificant while the effect from a negative tax shock is significant. Table 3 (row 3) also reports that the aggregate coefficients associated with these sign dependent tax shocks are not significantly different from one another. This is mainly because of large standard errors associated with the cumulative effects of a positive tax shock that results in a significant overlap between the impulse responses of output from a positive tax shock and a negative tax shock.

Impulse responses of these tax shocks illustrated in Figure 5 still suggest the possibility of asymmetric responses of output. For the positive tax shock the percentage change in output is very small and in addition 90% confidence interval also show very large standard errors. Therefore, at best, impulse responses and the coefficients in column 1 of Table 4 show insignificant changes in output due to a positive tax shock. However, looking at the impulse responses of output after a negative tax shock, it is unambiguously evident that output has increased significantly. The level of output increases by approximately 2% to 4% by the 8th quarter. The estimated coefficeints on the contemporaneous value and atleast 8 lags reported in column 2 of Table 4 shows an increase in output levels. Beyond lag 10, output decreases but it stays persistently above 0.19

For robustness, we redo the analysis based on single equation approach but instead of using exogenous tax shocks identified in Romer and Romer (2010), we use the traditional tax measure of changes in cyclically adjusted tax revenues. The significance test for the

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19One version of the single equation approach used in Romer and Romer (2010) includes lagged changes in output levels as an additional variable. We do not include this term in our analysis for clearer exposition of asymmetric effects of output. However, our results are also robust to inclusion of this additional variable.
coefficients and the difference between the two cumulative coefficients (row 3 in Table 5), again reveal the same conclusions as we found in the preceding analysis (i.e., with Romer and Romer (2010) exogenous tax shocks). Results based on this alternative measure are qualitatively very similar and therefore they also point to the asymmetric responses of output following the sign dependent tax shock.

To explore the dynamic effects of tax shocks, we implement the VAR approach (specification 3) using our baseline measure of Romer and Romer (2010) exogenous tax shocks. Our primary results are reported in the impulse responses of output to a positive and a negative tax shock in Figure 6, respectively. The impulse responses reveal that the response of output to a tax shock depends strongly on the sign of the underlined tax shock (i.e., whether the tax shock is positive or negative) and hence exhibits asymmetric effects: The positive tax shock has an insignificant effect on output while positive, permanent and significant effect on output is evident following a negative tax shock. Initiation of a negative shock pushes output upwards monotonically until the first 10 quarters and then it decreases again but still remains permanently sufficiently above 0. This reflects that since the inception of a negative tax shock, a permanent positive effect on output for at least 20 quarters is vividly evident. Furthermore, the 90th percentile confidence interval also confirms this observation. However, given the impulse responses, we can at best say that there is almost negligible effect on output from positive taxes if any. We call this permanent type of asymmetry resulting from different effects of a positive and a negative tax shock on output as Asymmetric tax effects.

As a robustness check, we repeat VAR approach, with cyclically adjusted tax revenue as an alternative measure of tax shocks. The corresponding impulse response is provided in Figure 9. Dynamic effects reveal that by the 20th quarter quantitatively the coefficient of lags is about 0.5% smaller compared to the effects estimated using the Romer and Romer (2010) tax shocks however, qualitatively, similar asymmetric effects of tax shocks are again prevalent with changes in cyclically adjusted tax revenue as the shock measure.

4.2. Results: Non-linear Approach

Using the methodology described in Section 3.2, we present the responses of output to a positive tax shock in the first panel of Figure 10 and a negative tax shock in second panel of Figure 10. The tax shock is a 1% change in tax liabilities normalized to GDP. Results based on Romer and Romer (2010) tax measure are plotted as a red line in each panel and it is evident that a positive tax shock does not affect output systematically while clear dynamics of output are evident through the red line in the right panel. The right panel shows that the output increases persistently, positively and significantly after a negative tax shock.

For robustness, the same analysis is done with cyclically adjusted tax revenue measure and
the subsequent results are shown as the magenta impulse response in Figure 10. Comparing the red and magenta plots shows that the qualitative asymmetric effects of output are robust to the alternative negative tax shock measure. Linear impulse responses from the previous section are also reported for reference. In each case, the response of real GDP (output) to either a 1% positive Romer and Romer (2010) tax shock or cyclically adjusted tax revenue change (both as a percentage of GDP) is not systematic with both linear and non-linear specification. Instead the response of output is erratic and fluctuates (with large standard errors) around zero in all 4 cases. The plot also illustrates that our earlier result documenting persistent, positive and permanent responses of output to a negative tax shock are robust to the two tax shock measures as well as linear and non-linear specifications. In particular, the right panel shows that the response of output to negative tax shocks is similar across all 4 impulse responses. We also find that the magnitudes of the responses are smaller when the responses are estimated through the non-linear methodology. This result is consistent with Kilian and Vigfusson (2011). Using Romer and Romer (2010) taxes, the maximum response of output is an increase of 3.14 percent using the linear methodology and it drops to 2.54 percent when non-linear methods are used. In both cases, the maximum increases occurs after 10 quarters of the initial shock. Using changes in cyclically adjusted tax revenues, the maximum increase in output is 1.91 percent using linear methodology while in the case of non-linear specification, the maximum increase drops is 1.75 percent. Both of these occur after the 9 quarter of the initial shock. Despite the numerical differences, the responses of output in non-linear impulse responses are qualitatively very similar to their linear counterparts.

5. Further Results and Discussion

Using the results documented in the preceding section, we conclude that responses of output level effectively show asymmetric effects following a sign dependent tax shock. To better understand this result, we further split positive and negative tax shocks into labor income and corporate income tax shocks which we jointly refer as “type dependent tax shocks”. Following Romer and Romer (2010), we also employ the 3 variable VAR approach separately for each sign and type dependent tax shock. The results for a positive and a negative labor income tax shock are presented in Figure 7 and a positive and a negative corporate tax shock are presented in Figure 8. By comparing Figure 7 and Figure 8 with Figure 6, it is quite evident that the asymmetric output responses documented in the preceding section is driven by a labor income tax shock and not by a corporate tax shock.

Now we extend our preceding analysis by using Romer and Romer (2010) tax shocks to examine the effects of sign dependent tax shocks (positive and negative) and pairwise sign

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and type dependent tax shocks (positive-labor, negative-labor, positive-corporate, negative-corporate tax shock pairs) on the following macroeconomic variables: (1) Investment (2) Consumption (3) Capital (4) Total and average hours (5) Wages and (5) Total Factor productivity and labor productivity. Table 6 summarizes the estimated effects of sign dependent and type dependent tax shocks on these macroeconomic variables. Corresponding impulse responses are also illustrated in Figure 11 – Figure 16. Our intent in characterizing the impulse responses of these macroeconomic variables (in addition to output) is to gain further insight about the factors driving the asymmetric effects on output documented in Section 4.

The key result of this additional analysis is that the asymmetric transmission of output in response to the sign dependent tax shock can be explained via “Ratchet effect” of consumption and labor supply. Assume a positive tax shock. Such a tax shock has a direct detrimental effect on disposable income. A consumer demonstrating ratchet effect will then resist a decrease in consumption in response to a lower income by utilizing her savings or by increasing her labor hours or a combination of both. These are exactly the results we observe after a positive tax shock. Now assume a negative tax shock. This enhances the income stream and a labor demonstrating ratchet effect resists substituting a unit of labor with leisure. This can be mainly due to the associated implicit costs (contractual costs of job, cost of re-entering the labor market) of decreasing work hours and implicit benefits (learning experience and enhancement of human capital) of uninterrupted work experience. In addition, higher income can also potentially increase savings. The results of the variable of interest behave very close to these theoretical predictions.

Consolidating these theories with a neo-classical production function provides a channel to understand the documented asymmetric effect of a tax shock on output. Implications of a negative tax shock are straightforward. Our results indicate small effect on labor supply (which is consistent with the ratchet effect) but a positive effect on capital (which is related to the ratchet effect of consumption). These results along with no significant effect on total factor productivity, can in a neo-classical framework suggest an increase in output. However, an implication of a positive tax shock on output is not as straightforward. Our results indicate that a capital input decreases (due to ratchet effect of consumption) and it is substituted with labor input (due to ratchet effect of labor). Based on this substitution along with a decrease in total factor productivity, output levels do not change in response to a positive tax change. When we use the accounting approach where we incorporate the effects of total factor productivity, labor and capital together, they add up to show that there is no significant change in output levels. This confirms that a decrease in capital and productivity parameter is offset by the increase in labor.

Below we present these results for each of the macroeconomic variables listed above:

- Results for total factor productivity (TFP) are presented in panel (1,1) of Figure 11 – Figure 16. Three key observations are evident: (1) TFP increases when the economy
is hit with a negative total tax shock (see panel (1,1) of Figure 11) and labor income tax shock (see panel (1,1) of Figure 13); (2) TFP does not respond much to a positive tax shock (see panel (1,1) of Figure 12, 14 and 16); (3) No response is administered for TFP with a corporate tax shock (see panel (1,1) of Figure 15 and Figure 16. Like output, asymmetric responses of TFP to sign and type dependent tax shocks are also evident.\footnote{Whether TFP is endogenous - and can be affected by policy variables such as tax changes - is a research question in itself. Some studies employ firm level data to show that firm level productivity is affected by changes in taxes. See Gemmell et al. (2013) and Arnold and Schwellnus (2008). Heylen and Schoonackers (2011) show that personal income taxes have negative effect on labor productivity. An important contribution in this literature has been by Mertens and Ravn (2010) who show that tax changes have long run effects on labor productivity. This result is very important in that it invalidates the traditional long run restrictions used in empirical analysis of macroeconomic effects of productivity shocks.}

- Capital responses show no asymmetry. The magnitude of the changes in capital (in percentage terms) as a consequence of a negative tax shock and a positive tax shock is comparable (see panel (1,2) of Figure 11 – Figure 16). Capital decreases with a positive tax shock and increases with a negative tax shock and no significant asymmetry is evident from the results.

- Total Hours and Average Hours have unidirectional effect for, both positive and negative tax shocks (see panel (1,3) for Total hours, and panel (2,2) for average hours in Figure 11 – Figure 16). It is clear from these impulse responses that these variables increase by a smaller magnitude as a result of a negative tax shock as compared to the increase following a positive tax shock. Only a positive tax shock has significant effect on these variable and like output, these variables are also inert to a corporate tax shock.

- Wages respond negatively to a positive tax shock. These results are not only driven by a labor income tax shock but also by a corporate tax shock. Wages remain inert to a negative tax shock of any type (see panel (2,3) of Figure 11 – Figure 16). This variable shows an upward stickiness, i.e, wages decline easily but do not rise.

- Impulse responses of labor productivity are also closely related to responses of output to a sign dependent and type dependent tax shock. Panel (3,1) of Figure 11 – Figure 16, show four key observations: (1) Labor productivity increases with a negative total and labor income tax shock and (2) It decreases with a positive tax shock (3) In addition, the magnitude by which labor productivity decreases following a positive tax shock is much higher than the magnitude by which it increases following a negative tax shock and (4) It does not show any significant response to a corporate tax shock. Using observation 1 and 3, this variable responds significantly to a positive tax shock rather than a negative tax shock (while opposite is true for output).
• Consumption exhibits asymmetry. (1) Impulse responses of consumption in panel (3,2) of Figure 11 – Figure 16 shows that consumption is unchanged following a positive tax shock (See panel (3,2) of Figure 12, 14 and 16) while it has a positive effect due to a negative tax shock (See panel (3,2) of Figure 11, 13 and 15), (2) Corporate tax shock (both a positive or a negative tax shock) has no effect on consumption. Consumption therefore, seems to behave in line with ratchet effect and it exhibits similar asymmetric responses as output (See panel (3,2) of Figure 15 and Figure 16).

• Investment responses are illustrated in panel (3,3) of Figure 11 – Figure 16. The key result is that investment behaves almost symmetrically to sign dependent (i.e., positive and negative) tax shocks. Additionally, investment responses to these tax shocks are very large and significant. This is mainly because both type dependent (labor income and corporate) tax shocks have very large effects on investment.

Jointly these results corroborate the theory of ratchet effect of consumption (since consumption only responds to a negative tax shock) and labor supply (since labor supply only responds to a positive tax shock). This ratchet effect of labor supply results in an asymmetric trade-off between labor and leisure. Together these results provide further insights for the asymmetric responses of output to a tax shock (i.e., output has an insignificant response to a positive tax shock and a significant positive response to a negative tax shock).

6. Conclusion

In this paper, we have presented empirical evidence of asymmetric responses of the output to sign dependent tax shocks. In particular, we find a negative tax shock to have persistent and significantly positive effect on output while a positive tax shock has no systematic effect on output. Further refinement of tax shocks into labor income and corporate tax shocks, reveal that the asymmetric responses of output are a product of labor income tax shocks rather than corporate tax shocks.

We also estimate impulse responses of other macroeconomic variables that are tied closely with output via a neo-classical framework, and found that consumption and labor supply exhibit “ratchet effect”, i.e, consumption responds (positively) only to a negative tax shock while labor supply responds (positively) only to a positive tax shock. In addition, total factor productivity (TFP) responds similar to consumption while capital and investment show no asymmetry and both increase after a negative tax shock and both decrease following a positive tax shock. Incorporating these responses in a neo-classical framework provide a potential explanation for the observed asymmetry of output responses to the sign dependent tax shocks.
A theoretical macroeconomic model that matches the empirical findings documented in this paper is an interesting future research topic and is one of our ongoing research projects. In addition, estimation of threshold effects of output can be a natural extension to further understand the empirical findings of this paper.
References


Heylen, F. and Schoonackers, R. (2011). Fiscal policy and tfp in the oecd: A non-stationary panel approach. Working Papers of Faculty of Economics and Business Administration, Ghent University, Belgium 11/701, Ghent University, Faculty of Economics and Business Administration.


### Table 1: Data Sources

<table>
<thead>
<tr>
<th>Variables</th>
<th>Data Source</th>
<th>Time Period</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corporate tax shocks</td>
<td>Mertens and Ravn (2011)</td>
<td>1947 - 2007</td>
<td>Quarterly</td>
</tr>
<tr>
<td>Total hours</td>
<td>Mertens and Ravn (2011)</td>
<td>1947 - 2007</td>
<td>Quarterly</td>
</tr>
<tr>
<td>Output</td>
<td>Bureau of Economics Analysis</td>
<td>1947 - 2007</td>
<td>Quarterly</td>
</tr>
<tr>
<td>Investment</td>
<td>Bureau of Economics Analysis</td>
<td>1947 - 2007</td>
<td>Quarterly</td>
</tr>
<tr>
<td>Consumption</td>
<td>Bureau of Economics Analysis</td>
<td>1947 - 2007</td>
<td>Quarterly</td>
</tr>
</tbody>
</table>

Notes: Table 1 reports the data sources, time period and frequency of the variables used in this paper.

### Table 2: Tax Changes: Summary

<table>
<thead>
<tr>
<th>Tax Change</th>
<th>No. of Non-Zero</th>
<th>Mean</th>
<th>Std.Dev</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR Positive</td>
<td>19</td>
<td>0.0025</td>
<td>0.0017</td>
<td>0.006</td>
</tr>
<tr>
<td>RR Negative</td>
<td>22</td>
<td>-0.0053</td>
<td>0.0048</td>
<td>-0.018</td>
</tr>
<tr>
<td>CATR Positive</td>
<td>179</td>
<td>0.0034</td>
<td>0.0031</td>
<td>0.021</td>
</tr>
<tr>
<td>CATR Negative</td>
<td>64</td>
<td>-0.0035</td>
<td>0.0045</td>
<td>-0.024</td>
</tr>
</tbody>
</table>

Notes: Table 2 reports the associated statistics to different tax changes. RR Positive (Negative) refer to Romer and Romer (2010) positive (negative) tax changes and CATR positive (negative) refers to positive and negative cyclically adjusted tax revenues.
Table 3: F Tests: Single Equation Approach

<table>
<thead>
<tr>
<th>Type : Tax Shock</th>
<th>Test</th>
<th>(Test Statistic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta_p^+ ) Positive</td>
<td>F(1, 205)</td>
<td>= 0.05</td>
</tr>
<tr>
<td>Prob &gt; F</td>
<td>= 0.8322</td>
<td></td>
</tr>
<tr>
<td>( \beta_n^- ) Negative</td>
<td>F(1, 205)</td>
<td>= 5.88</td>
</tr>
<tr>
<td>Prob &gt; F</td>
<td>= 0.0162</td>
<td></td>
</tr>
<tr>
<td>( \beta_p^+ - \beta_n^- ): Positive - Negative</td>
<td>F(1, 205)</td>
<td>= 1.29</td>
</tr>
<tr>
<td>Prob &gt; F</td>
<td>= 0.2571</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Table 3 reports significance test of the aggregate coefficients corresponding to the following regression specification:\[ \Delta y_t = \alpha + \sum_{p=0}^M \beta_p^+ \tau_t^+ + \sum_{n=0}^M \beta_n^- \tau_t^- + \epsilon_t \] where tax shock measure is exogenous Romer and Romer (2010) tax shocks (For more detail see single equation methodology presented in Section 3.1). Row 1 shows that the aggregate coefficient of output corresponding to a positive tax shock is insignificant while Row 2 shows that the aggregate coefficient of output corresponding to a negative tax shock is significant. Lastly, Row 3 shows that these two coefficients are not significantly different from each other.

Table 4: Effect of Tax Changes on Output Growth

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimated Impact of Positive Changes</th>
<th>Estimated Impact of Negative Changes</th>
<th>Estimated Multiplier of Positive Changes</th>
<th>Estimated Multiplier of Negative Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lag 0</td>
<td>0.5101</td>
<td>0.1098</td>
<td>0.5101</td>
<td>0.1098</td>
</tr>
<tr>
<td>Lag 1</td>
<td>-0.3694</td>
<td>-0.1984</td>
<td>0.1407</td>
<td>0.0748</td>
</tr>
<tr>
<td>Lag 2</td>
<td>0.6217</td>
<td>0.1634</td>
<td>0.7624</td>
<td>-0.3005</td>
</tr>
<tr>
<td>Lag 3</td>
<td>-0.8599</td>
<td>-0.3753</td>
<td>-0.0975</td>
<td>-0.6662</td>
</tr>
<tr>
<td>Lag 4</td>
<td>-0.2147</td>
<td>-0.3657</td>
<td>-0.3121</td>
<td>-0.9856**</td>
</tr>
<tr>
<td>Lag 5</td>
<td>0.0725</td>
<td>-0.3194</td>
<td>-0.2396</td>
<td>-1.3932**</td>
</tr>
<tr>
<td>Lag 6</td>
<td>-0.4076</td>
<td>0.0662</td>
<td>-2.2575**</td>
<td></td>
</tr>
<tr>
<td>Lag 7</td>
<td>-0.7487</td>
<td>-0.8645***</td>
<td>-0.6825</td>
<td>-2.6886***</td>
</tr>
<tr>
<td>Lag 8</td>
<td>0.6375</td>
<td>-0.4309</td>
<td>-0.045</td>
<td>-3.103**</td>
</tr>
<tr>
<td>Lag 9</td>
<td>-0.0155</td>
<td>-0.4143</td>
<td>-0.0606</td>
<td>-3.1449**</td>
</tr>
<tr>
<td>Lag 10</td>
<td>-0.0152</td>
<td>-0.0419</td>
<td>-0.0758</td>
<td>-2.7918**</td>
</tr>
<tr>
<td>Lag 11</td>
<td>0.7189</td>
<td>0.353</td>
<td>0.6431</td>
<td>-2.5732**</td>
</tr>
<tr>
<td>Lag 12</td>
<td>-0.0715</td>
<td>0.2187</td>
<td>0.5716</td>
<td>-2.5659***</td>
</tr>
</tbody>
</table>

Notes: Table 4 reports coefficients for the regression specification:\[ \Delta y_t = \alpha + \sum_{p=0}^M \beta_p^+ \tau_t^+ + \sum_{n=0}^M \beta_n^- \tau_t^- + \epsilon_t \] where tax shock measure is exogenous Romer and Romer (2010) tax shocks (For more detail see single equation methodology presented in Section 3.1). Following Romer and Romer (2010), we use 12 lags and the corresponding coefficients for a positive and a negative tax shock for each lag are provided in column 1 and column 2 of this table. Column 3 and column 4 provide the cumulative effect (multiplier effect) from the point of initiation of tax shock to the specific lag of a positive and a negative tax shock, respectively.
Table 5: F Tests : Single Equation Approach

<table>
<thead>
<tr>
<th>Type : Tax Shock</th>
<th>Test</th>
<th>(Test Statistic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta^+_p$ : Positive</td>
<td>$F(1, 204)$</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>Prob $&gt; F$</td>
<td>0.6046</td>
</tr>
<tr>
<td>$\beta^-_n$ : Negative</td>
<td>$F(1, 204)$</td>
<td>5.72</td>
</tr>
<tr>
<td></td>
<td>Prob $&gt; F$</td>
<td>0.0177</td>
</tr>
<tr>
<td>$\beta^+_p - \beta^-_n$ : Positive - Negative</td>
<td>$F(1, 204)$</td>
<td>2.29</td>
</tr>
<tr>
<td></td>
<td>Prob $&gt; F$</td>
<td>0.1321</td>
</tr>
</tbody>
</table>

Notes: Table 5 reports significance test of the aggregate coefficients corresponding to the following regression specification: $\Delta y_t = \alpha + \sum_{p=0}^{M} \beta^+_p \tau^+_t - \sum_{n=0}^{M} \beta^-_n \tau^-_t + \epsilon_t$ where tax shock measure is changes in cyclically adjusted tax revenue (for more detail see single equation methodology presented in Section 3.1). Row 1 shows that the aggregate coefficient of output corresponding to a positive tax shock is insignificant while Row 2 shows that the aggregate coefficient of output corresponding to a negative tax shock is significant. Lastly, Row 3 shows that these two coefficients are not significantly different from each other.

Table 6: Summary: Effects of Tax Shocks

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Total +</th>
<th>Income +</th>
<th>Corporate +</th>
<th>Total -</th>
<th>Income -</th>
<th>Corporate -</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td>No change</td>
<td>No change</td>
<td>No change</td>
<td>Increase</td>
<td>Increase</td>
<td>No change</td>
</tr>
<tr>
<td>Investment</td>
<td>Decrease</td>
<td>Decrease</td>
<td>Decrease</td>
<td>Increase</td>
<td>Increase</td>
<td>Increase</td>
</tr>
<tr>
<td>Consumption</td>
<td>No change</td>
<td>No change</td>
<td>No change</td>
<td>Increase</td>
<td>Increase</td>
<td>No change</td>
</tr>
<tr>
<td>Capital</td>
<td>Decrease</td>
<td>No change</td>
<td>No change</td>
<td>Increase</td>
<td>Increase</td>
<td>Increase</td>
</tr>
<tr>
<td>Total Hours</td>
<td>Increase</td>
<td>Increase</td>
<td>No change</td>
<td>No change</td>
<td>No change</td>
<td>No change</td>
</tr>
<tr>
<td>Average Hours</td>
<td>Increase</td>
<td>Increase</td>
<td>No change</td>
<td>No change</td>
<td>No change</td>
<td>No change</td>
</tr>
<tr>
<td>Employment</td>
<td>Increase</td>
<td>Increase</td>
<td>No change</td>
<td>Increase</td>
<td>Increase</td>
<td>No change</td>
</tr>
<tr>
<td>Wages</td>
<td>Decrease</td>
<td>Decrease</td>
<td>Decrease</td>
<td>No change</td>
<td>No change</td>
<td>No change</td>
</tr>
<tr>
<td>TFP</td>
<td>No change</td>
<td>No change</td>
<td>No change</td>
<td>Increase</td>
<td>Increase</td>
<td>No change</td>
</tr>
<tr>
<td>Labor Productivity</td>
<td>Decrease</td>
<td>Decrease</td>
<td>No change</td>
<td>Increase</td>
<td>Increase</td>
<td>No change</td>
</tr>
</tbody>
</table>

Notes: Table 6 summarizes the impulse responses of various macroeconomic variables to a sign dependent and type dependent tax shock. The effects on each variables corresponding to: (1) total positive tax shock are reported in column 1, (2) labor positive tax shock are reported in column 2, (3) corporate positive tax shock are reported in column 3 (4) total negative tax shock are reported in column 4, (5) labor negative tax shock are reported in column 5 and (6) corporate negative tax shock are reported in column 6. The corresponding impulse responses are also illustrated in Figure 11 - 16.
Notes: Figure 1 illustrates the frequency, magnitude and timings of a positive and negative Romer and Romer (2010) tax change. Each tax change is permanent and exogenous. Source: Romer and Romer (2010)

Notes: Figure 2 illustrates the frequency, magnitude and timings of a positive and negative cyclically adjusted tax revenue change. Source: Romer and Romer (2010)
Notes: Figure 3 illustrates the frequency, magnitude and timings of a positive and negative *Romer and Romer (2010)* labor income tax change. Each tax change is permanent and exogenous. Source: Romer and Romer (2010) & Mertens and Ravn (2013a)

Notes: Figure 4 illustrates the frequency, magnitude and timings of a positive and negative *Romer and Romer (2010)* corporate income tax change. Each tax change is permanent and exogenous. Source: Romer and Romer (2010) & Mertens and Ravn (2013a)
Figure 5: Impulse response of output: Single equation - R & R tax measures

Notes: Figure 5 illustrated impulse responses corresponding to a positive and a negative Romer and Romer (2010) tax shock. The impulse responses are estimated using the single equation approach (Details of the single equation approach are provided in section 3.1). The dashed lines indicate one standard error confidence bands. The standard errors were computed by taking 5,000 draws of coefficient vector from a multivariate normal distribution with mean equal to the estimates of the coefficients from the equation and variance-covariance matrix equal to the variance-covariance of the estimated coefficients. (For more details, see Romer and Romer (2010).)
Figure 6: Impulse response of output: VAR - R & R tax measures

Notes: Figure 6 illustrated impulse responses corresponding to a positive and a negative Romer and Romer (2010) tax shock. The impulse responses are estimated using 3 variable VAR approach with 12 lags (For specification details see Equation 3 and For more details on the VAR approach see Section 3.1). The dashed lines indicate 90% confidence intervals. Real GDP (output) is ordered first and is followed by a positive tax change variable and then a negative tax change variable. Results are robust to the ordering of the variables. Identification for this approach is embedded in the assumption that exogenous tax changes can be identified from narrative records.
Figure 7: Impulse response of output: VAR - Labor income R & R tax measures

Notes: Figure 7 illustrated impulse responses corresponding to a positive and a negative Romer and Romer (2010) labor income tax shock. The impulse responses are estimated using 3 variable VAR approach with 12 lags (For specification details see Equation 3 and For more details on the VAR approach see Section 3.1). The dashed lines indicate 90% confidence intervals. Real GDP (output) is ordered first and is followed by a positive tax change variable and then a negative tax change variable. Results are robust to the ordering of the variables. Identification for this approach is embedded in the assumption that exogenous tax changes can be identified from narrative records.
Figure 8: Impulse response of Output: VAR - Corporate R & R tax measures

Notes: Figure 8 illustrated impulse responses corresponding to a positive and a negative Romer and Romer (2010) corporate income tax shock. The impulse responses are estimated using 3 variable VAR approach with 12 lags (For specification details see Equation 3 and For more details on the VAR approach see Section 3.1). The dashed lines indicate 90% confidence intervals. Real GDP (output) is ordered first and is followed by a positive tax change variable and then a negative tax change variable. Results are robust to the ordering of the variables. Identification for this approach is embedded in the assumption that exogenous tax changes can be identified from narrative records.
Figure 9: Impulse response of output: VAR - Cyclically adjusted tax revenues (CATR tax measures)

Notes: Figure 9 illustrated impulse responses corresponding to a positive and a negative changes in cyclically adjusted tax revenues. The impulse responses are estimated using the single equation approach: (Details of the single equation approach are provided in section 3.1). The dashed lines indicate one standard error confidence bands. The standard errors were computed by taking 5,000 draws of coefficient vector from a multivariate normal distribution with mean equal to the estimates of the coefficients from the equation and variance-covariance matrix equal to the variance-covariance of the estimated coefficients. (For more details, see Romer and Romer (2010).)
Figure 10: Non Linear impulse response of output: total positive and negative R & R and CATR tax shocks

Notes: Figure 10 plots impulse responses of output to Romer and Romer (2010) tax shocks (illustrated by a red line and denoted as RR Non-Linear) and changes in cyclically adjusted tax revenues (illustrated by a magenta line and denoted as CATR Non-Linear) by using a non-linear specification based on Kilian and Vigfusson (2011). (See Section 3.2 for more details on the methodology.) The impulse responses are average of the impulse responses computed for each possible history. Impulse response for a particular history is computed by taking the difference of two simulated paths of real GDP (output), one in which the tax shocks were randomly drawn from the empirical series, and the second in which the same tax values were used as in the first one except for one change: the first value of the particular tax series was set to a constant $\delta$ where $\delta$ was the size of the shock given to the tax series. The paths for real GDP (output) were simulated using the coefficients estimated through a regression of real GDP (output) on 12 lags of a negative and a positive tax change. For reference, impulse responses of output to Romer and Romer (2010) tax shock (illustrated by a blue line and denoted by RR Linear) and changes in cyclically adjusted tax revenues (illustrated by a black line and denoted by CATR Linear) using a single equation approach are also illustrated.
Figure 11: Impulse response of macroeconomic variables: Total negative R & R tax measures

Figure 11 illustrates the effect of a negative Romer and Romer (2010) tax shock on various macroeconomic variables. The impulse responses are estimated using an extension of a 3 variable VAR approach presented in more detail in Section 3.1. The specification used here includes variables in the following order: real GDP (output), positive tax shocks, negative tax shocks and an additional macroeconomic variable of interest. The dashed lines represent the 90 percent confidence intervals.
Notes: Figure 12 illustrates the effect of a positive Romer and Romer (2010) tax shock on various macroeconomic variables. The impulse responses are estimated using an extension of a 3 variable VAR approach presented in more detail in Section 3.1. The specification used here includes variables in the following order: real GDP (output), positive tax shocks, negative tax shocks and an additional macroeconomic variable of interest. The dashed lines represent the 90 percent confidence intervals.
Figure 13 illustrates the effect of a negative Romer and Romer (2010) labor income tax shock on various macroeconomic variables. The impulse responses are estimated using an extension of a 3 variable VAR approach presented in more detail in Section 3.1. The specification used here includes variables in the following order: real GDP (output), positive tax shocks, negative tax shocks and an additional macroeconomic variable of interest. The dashed lines represent the 90 percent confidence intervals.
Figure 14: Impulse response of macroeconomic variables: Labor income positive R & R tax measures

Notes: Figure 14 illustrates the effect of a positive Romer and Romer (2010) labor income tax shock on various macroeconomic variables. The impulse responses are estimated using an extension of a 3 variable VAR approach presented in more detail in Section 3.1. The specification used here includes variables in the following order: real GDP (output), positive tax shocks, negative tax shocks and an additional macroeconomic variable of interest. The dashed lines represent the 90 percent confidence intervals.
Figure 15: Impulse response of macroeconomic variables: Corporate negative R & R tax measures

Notes: Figure 15 illustrates the effect of a negative Romer and Romer (2010) corporate tax shock on various macroeconomic variables. The impulse responses are estimated using an extension of a 3 variable VAR approach presented in more detail in Section 3.1. The specification used here includes variables in the following order: real GDP (output), positive tax shocks, negative tax shocks and an additional macroeconomic variable of interest. The dashed lines represent the 90 percent confidence intervals.
Figure 16 illustrates the effect of a positive Romer and Romer (2010) corporate tax shock on various macroeconomic variables. The impulse responses are estimated using an extension of a 3 variable VAR approach presented in more detail in Section 3.1. The specification used here includes variables in the following order: real GDP (output), positive tax shocks, negative tax shocks and an additional macroeconomic variable of interest. The dashed lines represent the 90 percent confidence intervals.