Asymmetric Effects of Tax Changes

Syed M. Hussain * Samreen Malik †

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Abstract

We study whether output responds symmetrically to exogenous tax increases (“positive” shock) and decreases (“negative” shock) in postwar US data using the identification in Romer and Romer (2010). Our key result shows significant asymmetry: output responds insignificantly to a tax increase, but shows a significantly positive and permanent increase to a tax decrease. This result is robust to alternative tax shock measures such as cyclically-adjusted-tax-revenues and unanticipated tax shocks. Further analysis reveals that our key result of asymmetric responses of output is driven by individual income tax shocks and transmitted to the economy through asymmetric response of consumption to these shocks.

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

*Department of Economics, Lahore University of Management Sciences, Lahore, Pakistan, Email: muhammad.hussain@lums.edu.pk
†Department of Economics, New York University - Abu Dhabi, Email: samreen.malik@nyu.edu
1. Introduction

The existing literature studying the effects of tax shocks on output generally assumes that a tax increase (a positive shock) and a tax decrease (a negative 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 by Romer and Romer (2010) (and measured as the change in tax liabilities as a percentage of GDP). We categorize 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). We compute linear impulse responses in a single equation framework in which real output growth is regressed on its own lags and lags of our positive and negative measures of tax shocks. We also compute non-linear impulse responses following Kilian and Vigfusson (2011) in order to guard against the potential shortcomings of studying the presence of asymmetry through linear approaches.

Our key finding is that positive and negative tax shocks have an asymmetric effect on aggregate output. In particular, the estimated effect of a positive tax shock on output is insignificant while output increases approximately by 3.0% at the peak, following a negative tax shock. This key result is also robust to cyclically-adjusted-tax-revenue changes as an alternative tax shock measure which has been traditionally used in the macroeconomic literature. Additional analyses that explore the effects of positive and negative unanticipated tax shocks, also exhibit a similar asymmetry.

\(^1\)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 result is that tax cuts have very large and persistent positive output effects.”.
Next, following Mertens and Ravn (2013), we classify the Romer and Romer (2010) exogenous tax shocks into individual income tax shocks and corporate income tax shocks. This analysis reveals that the asymmetry in output responses is mainly due to the significant effect of a negative individual income tax change on output. In particular, a negative individual income tax shock exhibits a significant positive impact of up to 2%. Additionally, output responses are symmetric following a positive and a negative corporate income tax changes. In particular, a negative corporate tax shock exhibits significant positive effect on output of about 1.3% while a positive corporate income tax shock exhibits about 1% negative effect on output.

To further investigate the channels for asymmetric response of output to positive and negative tax shocks, we examine the responses of other macroeconomic variables, especially consumption and investment, to these tax shocks. The main result show that like output, consumption has a strong asymmetric response to positive and negative tax shocks while investment responds almost symmetrically. In particular, consumption increases following a negative tax shock (by about 2.5% at the peak) while it does not exhibit any significant response to a positive tax shock. Investment, on the other hand, responds almost symmetrically (by up to $|11|\%$), following positive and negative tax shocks.

Finally, we investigate whether the asymmetric response of output to a positive and a negative tax shock, is driven by the size of these tax shocks. If the changes in negative taxes are relatively bigger than the changes in positive taxes then the bigger size of the negative tax shock may be a reason for the significant response of output growth following a negative tax shock. We find that the asymmetric effect of a positive and a negative tax shock is robust to various sizes of positive and negative tax shocks. In particular, positive tax shocks of size 0.25 standard deviation to size 20 standard deviation have an insignificant effect on output while negative tax shocks of size greater than 1 standard deviation have a significant effect on output. In addition, small negative tax shocks (of size $<1$ standard
deviation) exhibit an insignificant effect on output hence also pointing towards an additional size related asymmetry for output following negative tax shocks.

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 a state year panel data set to study the response of employment growth to military spending. Their main result is that employment growth across states is explained non linearly by military spending. In particular, they show that a large negative shock to military spending has bigger effect on employment than the effect from a positive shock to military spending. Overall, the non-linearity of variables of interest documented in the existing literature is owing to state dependence of fiscal policies. However, the main focus of our paper is to explore the non-linearity in the responses of output growth to positive and negative tax changes.

Numerous studies have looked at the effects of a tax shock on output growth without taking into account the possibility of an asymmetry stemming from the sign of the tax shock. Additionally, there is no general consensus over the magnitude of the effect of a tax shock on aggregate output growth. Seminal studies in this literature include Blanchard and Perotti (2002), Romer and Romer (2010) and Mertens and Ravn (2011). 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%.² 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 (of about 3%) with respect to tax changes.³ Mertens and Ravn (2011) use narrative tax shocks and distinguish between surprise and anticipated changes in tax liabilities. Using a VAR approach, they estimate the impact of these tax shocks on output and other macroeconomic aggregates. Their main result shows that an unanticipated tax cut gives rise to significant increase in output, consumption and investment. In particular, a one percent tax cut is associated with a 2% peak increase in output per capita. 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 the documented estimates.

The rest of the paper is organized as follows: Section 2 explains in detail the sources and construction of our data set. In Section 3, we describes in detail our methodology. Section 4 documents our results of: negative and positive Romer and Romer (2010) tax shocks on output, negative and positive unanticipated tax shock on output, positive and negative individual and corporate income tax shocks on output, various sizes of positive and negative tax shocks on output and finally responses of other macroeconomic variables such as consumption and investment to positive and negative tax shocks. Section 5 concludes.

²Blanchard 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.

³The 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.
2. Data

The main data on tax shocks covers the period 1947Q1 to 2007Q4 and it comes from Romer and Romer (2010). They study each major tax bill signed in the post-war era in the United States and 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.\(^4\) A tax shock is then the change in the nominal tax liabilities due to these “exogenous” tax changes 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 call these exogenous and permanent tax shocks as R & R tax shocks. We categorize these into negative tax shocks (resulting from the documented exogenous permanent 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 magnitude, time and sign of the tax shock measure are illustrated in Figure 1.

As a robustness check, we also use changes in cyclically-adjusted-tax-revenues. Cyclically-adjusted-tax-revenue is a standard measure of tax changes in the macroeconomic literature. This measure is designed to take into account the fact that tax revenues increase and decrease with GDP. These tax revenues are therefore measured on the basis of what revenue would be if GDP were at the normal trend

\(^4\)The 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.
level. Romer and Romer (2010) also use these nominal tax revenues normalized by chain-type price index of GDP. To facilitate the comparison of these tax shocks with R & R tax shocks, they compute the change in the real cyclically-adjusted-tax-revenues normalize by real GDP. In this series, the number of total positive tax shocks are 180 and total negative tax shocks are 64. However, Mertens and Ravn (2012b) has pointed out potential issues with cyclically-adjusted-tax-revenues and therefore we further de-mean the Romer and Romer (2010) constructed cyclically-adjusted-tax-revenue changes. In our de-meaned series, the number of total positive tax shocks are 115 and total negative tax shocks are 128. The timing and the magnitude of these sign dependent tax shock measures are illustrated in Figure 2.\(^5\)

We also divide the R & R tax shocks into anticipated and unanticipated tax measures. For this, we employ the methodology used by Mertens and Ravn (2011). Specifically, we define a tax change as anticipated if the enactment date of that particular tax reform is 90 days before the implementation date. The enactment date refers to the date when the President signs the tax reform whereas the implementation date refers to when the change in taxes actually take place.

Our measure of the unanticipated tax changes differs from that of Mertens and Ravn (2011) in one important way. Our underlying analysis explores the long-run effects of tax shocks and therefore we are only interested in permanent tax shocks. In particular, we are not considering the effects of temporary tax changes and therefore ignore the retroactive components of tax changes (which by definition are for one quarter and hence temporary) which are mainly employed in Mertens and Ravn (2011). Figure 3 illustrates the magnitude, time and sign of the unanticipated tax shock series over the sample period of 1947Q1 – 2007Q4.

We also use a finer break down of the R & R tax shocks into individual income income

\(^{5}\)Note the data covers the period 1947 Q2 - 2007 Q4. Our results are quantitatively similar with original cyclically-adjusted-tax-revenue changes employed in Romer and Romer (2010) and we do not include these results in the paper, to conserve space.
tax shock and corporate income tax shock. To do so, we use the narrative account (such as economic reports of the president and congressional budget office) from Mertens and Ravn (2013) to split the R & R tax shock series. Mertens and Ravn (2013) split the exogenous series into four categories: corporate income tax liabilities, individual income tax liabilities, employment taxes and a residual category with other revenue changing tax measures. Like Mertens and Ravn (2013), we also discard the latter group for the reasons of presence of considerable heterogeneity and group together individual income tax liabilities and employment taxes and jointly refer to this category of taxes as individual income taxes. Furthermore, we also normalize these two categories – individual income and corporate income tax changes – using contemporaneous personal taxable income and corporate taxable income respectively.\(^6\) Figure 4 and Figure 5, respectively illustrate size, time and sign of our individual income and corporate income tax shocks over the sample period of 1947Q1 – 2007Q4.\(^7\)

Data for quarterly real output, investment, and consumption are taken from Bureau of Economics Analysis (BEA).\(^8\) Data for the remaining macroeconomic variables are from various sources. The data on total factor productivity (TFP) is from Fernald (2012).\(^9\) 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

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\(^6\) This is a way to put all the tax changes on a consistent basis as employed in Mertens and Ravn (2013). In this way these tax changes can roughly be considered as changes in percentage points of average tax rates.

\(^7\) As we are interested in studying long-run effects of tax shocks, we abstract from retroactive and temporary tax shock measures. Therefore, our corporate and individual income tax shocks differ from the tax shocks used in Mertens and Ravn (2013).

\(^8\) These variables are measured using chain-type quantity index.

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. Methodology

We employ linear and non-linear methodologies to test whether positive and negative tax shocks have an asymmetric effect 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 the asymmetric effects of monetary shocks. 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 Methodology:

Let $\tau_t$ denote the shocks to taxes at time $t$. Define

$$\tau^+_t = \max(0, \tau_t), \quad \tau^-_t = \min(0, \tau_t)$$

as a positive and a negative shock to the tax process, respectively. Following the literature on the 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 by Ravn and Sola (2004), Cover (1992), and DeLong and Summers (1988) and many others.

Since Romer and Romer (2010) provide us with exactly these uncorrelated tax shocks, this makes the first step of estimation strategy redundant. In particular, Romer and Romer (2010) use narrative records of major tax bills in post-war US to document exogenous and endogenous tax changes. We only use the permanent exogenous tax shocks and further split these into positive and negative tax shocks (See Section 2 for more detail). Following Romer and Romer (2010), we use contemporaneous and 12 lagged values of these positive and negative exogenous tax shocks to estimate their effect on aggregate output growth. Specifically, we estimate the following equation:

\[
\Delta y_t = \alpha + \sum_{p=0}^{M} \beta_p^+ \tau_{t-p}^+ + \sum_{n=0}^{M} \beta_n^- \tau_{t-n}^- + \sum_{l=0}^{L} \beta_l \Delta y_{t-l} + \epsilon_t
\]  

(2)

where \(\Delta y_t\) is the growth rate of GDP. \(\tau_{t-p}^+\) and \(\tau_{t-p}^-\) are respectively, positive and negative exogenous tax shocks (change in tax liabilities due to exogenous and permanent tax changes as a percentage of nominal GDP). The sign + and - indicates a positive and a negative tax shock, respectively, 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 aggregate coefficient associated with negative tax shocks for \(M\) lags. Lastly, \(\Delta y_{t-l}\) is lagged values of the growth rate of GDP and \(\sum_{l=0}^{L} \beta_l\) aggregates the coefficient associated with \(L\) lags of output growth. Including lagged output growth, controls for the normal dynamics of output, the state of the economy and multitude of other serially correlated factors.\(^\text{10}\)

3.2. Non-Linear Methodology

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

\(^\text{10}\)See Romer and Romer (2010) for more detail.
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.

Furthermore, a linear methodology is restrictive in two ways. First of all, this methodology is based on a censored regression where all non-negative (non-positive) tax shocks are replaced with zeros when exploring the effect of a positive (negative) tax shock. This can potentially overestimate the implied effect of each type of a shock and therefore, the results can be misleading. Secondly, the linear methodology does not allow us to explore the effects of the size of the shock. This is because the computation of linear impulse response will be based on a simple linear combination of the estimates from the regression results. In addition, if output response is significant only for a certain size of the tax shock, then our results will be confounding size based asymmetry as sign based asymmetry. In particular, in our tax shock measure, on average, negative shocks are bigger than the positive tax shocks and abstracting from this size based analysis can therefore be misleading. These reasons call for a nonlinear size based estimation of impulse responses.\footnote{It must be noted that R & R tax shocks contain many zeros. Therefore, the first issue of censored regression is less pressing in our case than the second issue, described in the text. Step 2 and 3 enumerated in the Appendix A.1, will draw mostly zeros and therefore, we hypothesize that the impulse responses from the linear and non-linear methodology will be qualitatively similar to each other.}

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. In particular, computing non linear impulse responses based on the 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). Step by step detail of the methodology is provided in the Appendix A.1.

4. Results

We begin by documenting the effects of negative and positive exogenous and permanent tax shocks on output growth in Section 4.1. Throughout the results, we report impulse responses to a 1 percent change in tax liabilities (relative to GDP) along with 1 standard error, bootstrapped confidence intervals. The impulse responses are reported for a forecast horizon of 20 quarters.

The interpretation of the magnitude of the impulse response function is based on Equation 2. This equation captures a direct and an indirect effect of a positive and a negative tax liability change (relative to GDP). The direct effect is simply the sum of the coefficients on the contemporaneous value and the first M lags of the tax variable while the indirect effect stems from the coefficients from the lagged values of output growth. Non-linear impulse response is also computed from the estimates of the same equation, Equation 2 for a given shock. We, then average the impulse response draws obtained using various initial conditions and sequence of shocks, hence the interpretation of the impulse response estimates is the average sum of direct and indirect effect over different initial conditions and subsequent shocks.

Following Romer and Romer (2010), the standard errors for the linear methodology are computed by taking 10,000 draws of the coefficient vector from a multivariate normal distribution with mean and variance-covariance matrix equal to the point estimates and variance-covariance matrix of the regression coefficients. The standard errors corresponding to the non-linear impulse responses are computed from 20,000 bootstrap replications.
4.1. Basic Aggregate Results

Figure 6 display the impulse responses derived from both (linear and non-linear) methodologies for a negative tax shock and a positive tax shock. Our results indicate the presence of asymmetric effects of a positive and a negative tax shock on aggregate output growth: output responds significantly after a negative tax shock and insignificantly after a positive tax shock.

First, following the linear methodology (illustrated in Figure 6 with a blue line), the results show that after a negative tax shock i.e., a tax decrease of one percent of GDP, output responds insignificantly for the initial few quarters. It then shows a significant increase from the 8th quarter onward until the 13th quarter with the peak effect on output growth of 3.23 percent occurring at the 10th quarter. Quantitatively, similar results are found for a negative tax shock when we follow a non-linear methodology (illustrated in Figure 6 with a red line). Following non-linear methodology, the estimated maximum impact of a tax liability reduction (relative to GDP) of 1 percent again occurs at 10th quarter while the magnitude falls from 3.23 (t = 2.78) in the linear approach to 3.02 (t = 3.04) in the non-linear approach. The impulse response computed from the non-linear methodology is highly significant from the 8th quarter until the end of the horizon.\textsuperscript{13}

The implied effect of a negative tax liability change (relative to GDP) on aggregate output in our result is about 2.5 percent and it is similar to the result from Romer and Romer (2010) that uses the single equation specification (that also controls for lagged GDP growth). Relative to the VAR based estimates of unanticipated tax shock on output growth reported in Mertens and Ravn (2011), our estimates are slightly bigger. However, our initial response of output growth to a negative tax liability change occurs more gradually than Romer and

\textsuperscript{13}The results corresponding to the specification that excludes lagged GDP growth is suppressed to conserve space, however the documented results are robust to the exclusion of lagged output growth as the regressor.
Romer (2010) and is in line with Mertens and Ravn (2011)’s implied effect of unanticipated tax shocks for the first 7 quarters.

The above results from linear and non-linear methodology are not very different and therefore we only discuss the results based on non-linear methodology from here on. Without any exception, subsequent discussion of the results also holds when we employ linear methodology.

We also redo the baseline analysis with the “traditional” cyclically-adjusted-tax-revenue changes as the tax shock measure. The idea is to explore if our documented asymmetric response of output growth to a negative and a positive tax change is robust to this alternative tax measure. We again categorize the tax shock series, into negative and positive tax shocks and explore their respective effects on output growth using non-linear methodology.

Figure 7 illustrates the computed response of output growth to a negative and a positive cyclically-adjusted-tax-revenue change. We find that the results are qualitatively similar to the results from R & R shocks. The estimated implied effect of cyclically adjusted tax shocks on output growth reassures that the main finding of asymmetric effects on output growth responses is robust to these alternative tax shock measure. When comparing responses of output growth following R & R tax shocks and changes in cyclically-adjusted-tax-revenues, quantitatively some differences emerge. First, the magnitude and timing of the peak effect differs. The highest peak with the negative cyclically-adjusted-tax-revenues is about 2.3% (compared to 3.02% for negative R & R tax shocks) occurring in the second last quarter (compared to the peak effect occurring at the 10th quarter for negative R & R tax shocks). Second, on impact of a cyclically-adjusted positive tax shock, output growth increases for the initial quarters but only the 3rd quarter estimate is significant. This increase in output growth after a tax increase is an anomalous behavior of output growth. However, we do not see the same anomalous behavior of output growth after the R & R tax shocks where the estimates of a positive tax shock are largely insignificant and/or negative.
4.2. Unanticipated Tax Changes

Fiscal policies based on tax increases typically go into effect well after they are legislated, whereas policies based on tax reductions typically go into effect immediately.\(^{14}\) Any form of asymmetric lag, between the legislation and implementation of a positive and a negative tax shock, can very well be the source of asymmetric effects of these shocks on output. This would mean that the results documented in the last section could potentially be a result of a model misspecification.

In this section, we wish to explore how our key result (in Section 4.1) is modified as a result of restricting our analysis to only unanticipated permanent and exogenous Romer and Romer (2010) tax shocks. We call these tax shocks unanticipated R & R tax shocks.\(^{15}\) This modification will allow us to remove any anticipatory effect from our analysis.

Following Mertens and Ravn (2011), in addition to lagged GDP growth as the control, we also control for the effect on output growth due to anticipated tax shocks. Figure 8 displays the main result of this section and reveals that the effect on output growth due to a negative tax shock is significant while the effect after a positive tax shock is insignificant.

Furthermore, comparing these results (illustrated in Figure 8) to the estimation results based on R & R tax shocks (illustrated as red line in Figure 6), we find that the effects are now highly significant from the 3rd quarter until the 20th quarter, however, the estimated effect of a negative tax shock is now quantitatively almost doubled. The maximum effect again occurs at the 10th quarter and is approximately 7 percent of GDP growth.\(^{16}\)

It is not straightforward to compare our estimates with the estimates from

\(^{14}\)Perhaps due to political economy considerations, fiscal policies relying on tax increases are implemented with a lag versus policies relying on tax decreases. Such considerations could well induce an asymmetry into the response of output to positive versus negative tax shocks.

\(^{15}\)Construction of unanticipated tax shocks is provided in the Section 2.

\(^{16}\)We also redo the analysis without anticipated tax shocks and the results (not presented in this paper) are qualitatively similar. The estimates are only marginally different.
Mertens and Ravn (2011) since the tax shocks in our case are different from theirs (See Section 2). However, the stark increase in the effect of negative unanticipated R & R tax shocks relative to negative R & R tax shocks on output growth makes economic sense because unanticipated tax shocks should in principle have much bigger effect on output growth since no prior change in behavior is present that can dampen the effect on output growth. This entails that the shocks will have more significant and bigger effect on output growth. This is exactly what we see for these negative unanticipated R & R tax shocks. But more importantly, we still see a clear asymmetric responses of output growth to a negative and a positive tax shock. We, therefore, infer that the asymmetric effects, we found in our baseline results, are not stemming from anticipatory features of original R & R tax shocks.

4.3. Individual Income and Corporate Income Tax Changes

As argued in Mertens and Ravn (2013), there are many types of taxes available to the tax authorities for policy purposes and these various types of tax shocks may have different effects on output growth. Aggregating these various types of tax shocks into one composite tax shock to study the effect on output growth may mask the real effect. In this section, we wish to explore how output growth and in particular, the asymmetric effect on output growth due to a negative and a positive tax shock is affected when we use a more disaggregated tax measure. Like Mertens and Ravn (2013), we only consider two broad categories of tax measures: corporate and individual income taxes. Construction of these disintegrated tax measures is discussed in the data section, Section 2.

A major issue with individual income and corporate income tax liability changes is that these two types of tax measures are highly correlated because tax reforms typically change both measures simultaneously. This may violate the key exogeneity assumption in our regression equation. Therefore, like Mertens and Ravn
(2013), in addition to lagged GDP growth as a control, we also control for corpo-
rate income tax shock (individual income tax shock) when studying the effect of
individual income tax shock (corporate income tax shock) on output growth. The
impulse responses of output growth are then computed for positive and negative
tax shocks for each type of tax measure.

The results from the analysis that employs individual income tax shocks are
illustrated in Figure 9. The results reveal that negative individual income tax
shocks have long-term effect on output growth (of approximately 2% at the peak)
while positive tax shocks have insignificant effect on output growth. In particular,
though the negative individual income tax shocks have small and insignificant
effect on output for the first 10 quarters, the effect becomes significant for the
rest of the forecast horizon. However, this is not the case with the positive
individual income tax shocks.

Different results for output growth are exhibited from the analysis that em-
ists corporate income tax shocks (while controlling for individual income tax
shocks). In particular, Figure 10 illustrates that a positive corporate income tax
shock have a significant and a negative effect on output from the 6th quarter
till the 10th quarter. Subsequently, the estimated impact from the 10th quarter
until the end of the horizon is small and insignificant. The maximum effect on
output is about -1 percent after the 8th quarter. Where as the result from the
negative corporate tax shocks (also illustrated in Figure 10) show that there is a
significant and a positive effect on output for the first 10 quarters (with the peak
effect of 1.3% occurring at the 8th quarter). After that, the effect becomes small
and insignificant.

Positive and negative corporate income tax shocks do not exhibit a strong
asymmetric effect on output that we see in the case of individual income tax
changes. Therefore, we conclude that the asymmetric response of output observed
in Section 4.1 are mainly due to the asymmetric effects of individual income tax
shocks.
4.4. Size Asymmetry and Output Responses

Prior results and the estimation of impulse responses are based on a 1 percent change in a positive and a negative tax liability (relative to GDP). However, on average, in our main tax measure data (R & R tax shocks), the changes in negative tax liability (relative to GDP) are much larger than changes in positive tax liability (relative to GDP). If a tax change has to be of a certain size before eliciting a significant response of output growth, then the asymmetric results from Section 4.1, may in fact be driven by the bigger changes in negative taxes as compared to positive taxes. This can potentially confound the effect on output due to size asymmetry as sign asymmetry.

To explore this, we only employ the non-linear methodology as linear methodology does not allow us to explore the effects of size of the tax shocks on output. Instead of using 1 percent change in tax shocks, shock size is now measured in terms of the standard deviation of the tax shocks such that a shock size of 1 corresponds to 1 standard deviation of the positive tax shock and a shock size of -1 corresponds to 1 standard deviation of the negative tax shock. In terms of the non-linear methodology explained in Section 3.2 and corresponding step by step explanation of the methodology in Appendix A.1, we vary the size of $\delta$. In particular, the shock size will now be $\delta \sigma_{tax}$ where

$$\delta \in \pm\{0.25, 1, 2, 5, 10, 20\}$$

and $\sigma_{tax}$ is the standard deviation of the R & R tax shocks.

The impulse responses are illustrated in Figure 11. The impulse responses are all normalized by a factor $\delta \sigma_{tax}$. Two main results are evident. First in general, positive tax shocks of any size have insignificant effect on output growth and the magnitude of the small positive shocks (though mostly insignificant) are much bigger than the magnitude from the large positive shocks. However negative tax shocks, in general have significant effect on output for various sizes of tax shocks. In particular, interestingly we also find that relative to big negative tax shocks,
small negative tax shocks (i.e., tax shock of size < 1 standard deviation) have less significant impact on output growth.

These results reaffirm the asymmetric response of output after positive and negative tax shocks (as documented earlier). In addition this section also provides an evidence of another form of asymmetric effects of tax shocks of various sizes on output growth. In particular, small negative tax shocks of size less than 1 standard deviation, also exhibit insignificant effect on output growth.

4.5. Consumption, Investment and Other Macroeconomic Variables

So far, we have looked at the effects of tax changes on output alone. In this section, we seek to explore the effect of a negative and a positive tax change on other macroeconomic variables, especially consumption and investment, to understand the channels of the documented asymmetric responses of output.

In this section, we employ the following model (which mirrors our earlier specifications) to estimate the impulse responses of our variables of interest.\footnote{We depart from our earlier regression equation, Equation 2 and replace it with Equation 3 (which mirrors our earlier regression equation). The helps us to study the evolution of consumption, investment or other macroeconomic variable of interest along with the evolution of output after a positive and a negative tax shock. Furthermore, to capture the inter-dependencies in multiple time series, this specification is more fitting. We employ this specification in our non-linear methodology and then compute non-linear impulse responses.}

$$X_t = A + Bt + C(L)X_{t-1} + D(L)\tau_t^+ + E(L)\tau_t^- + \epsilon_t$$

This specification is in line with Mertens and Ravn (2012a) who show that this model corresponds to the dynamics of a DSGE model. $\tau_t^+$ and $\tau_t^-$ are exogenous positive and negative tax shocks. $X_t$ is a vector of endogenous variables. We run this model for 2 variables at a time, where the first variables is always output
and the other variable is one of our variables of interest.

\[ X_t = [Y_t, Z_t]' \]

where

\[ Z_t \in \{C_t, I_t, K_t, TH_t, EMP_t, AH_t, W_t, TFP_t, OPW_t\} \]

where \( C_t \) is consumption, \( I_t \) is investment, \( K_t \) is capital, \( TH_t \) is total hours worked, \( EMP_t \) is employment, \( AH_t \) is average hours per worker, \( W_t \) is real hourly wage, \( TFP_t \) is multi-factor productivity, and \( OPW_t \) is output per worker or labor productivity. The data sources for these variables are given in Table 1. All variables are in log forms. \( C(L) \) is a \( P \)-order lag polynomial and \( D(L) \) and \( E(L) \) are \( (R+1) \)-order lag polynomial. Following Mertens and Ravn (2012a) we choose \( R = 12 \) and \( P = 1 \). The results are robust to other choices of \( P \). This model is a vector autoregression in \( X_t \) treating the tax shocks as exogenous.

We estimate this model using non-linear methodology. The non-linear methodology is similar to the one explained in section 3.2.\(^{18}\) The output response following a positive and a negative tax shock is illustrated in Figures 12 and 13, respectively.

Since consumption and investment constitute a big portion of the output, we first discuss these results in detail and then provide a summary of results from the other macroeconomic variables. Consumption responds positively and significantly to negative tax shocks, with the peak effect of approximately 2.5% occurring at the 10th quarter. The effect is most pronounced for the middle quarters of the forecast horizons after which the effect becomes smaller and insignificant. Consumption response to positive tax shocks, on the other hand, is highly insignificant throughout the horizon forecast. Investment shows a symmetric response to positive and negative tax shocks. In particular, investment falls (at the peak by approximately 11%) in response to positive tax shocks and increases (at the peak by approximately 11%) in response to negative tax shocks.

\(^{18}\)Here we only present the results from the non-linear methodology for clarity but the results from linear methodology are virtually identical.
in the short-run before returning to its pre-shock levels in the long-run. These results suggest that between consumption and investment, asymmetric output responses are channeled through asymmetric consumption responses after positive and negative tax shocks. Furthermore, the symmetric response of capital also lends some credence to the symmetric response of investment.

Labor related variables such as total hours worked increase in the long-run in response to positive and negative tax shocks. This increase in total hours seems to be originating from a change in employment which also increases following positive and negative tax shocks (the increase is more in the case of a positive tax shock). Average hours per worker do not respond significantly to either of the tax shocks. In addition hourly wages fall significantly in the long-run following positive tax shocks whereas following negative tax shocks hourly wages seem to exhibit insignificant response. Labor productivity responds significantly for a few quarters following negative tax shocks but otherwise shows insignificant response to both, a negative and a positive tax shock. Like labor productivity, TFP in general does not seem to respond significantly to a positive or a negative tax shock.19

These overall results from this section provide interesting insights about the potential channels behind the asymmetric response of output growth to tax shocks. In summary the main findings of this section are that: (i) consumption response is asymmetric while investment response is symmetric (ii) hours worked increase significantly following a positive tax shock (iii) wages decrease significantly following a positive tax shock and (iv) consumption does not respond

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19Whether 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.
significantly to a positive tax shock. Jointly these results suggest that workers resist downward changes in consumption or in other words consumption is sticky downwards and hence workers increase working hours to compensate decrease in wages and after-tax (disposable) income.

One way to reconcile our empirical results into theoretical framework is to think of a simple neo-classical model with firms and household as the agents in the economy. In such a setting, negative and positive tax shocks will have opposite but symmetric effects on output. However, if household’s consumption is sticky downwards, then a positive tax shock will not have significant effect on consumption. The agents will substitute leisure and investment for maintaining their prior consumption level. On the other hand with a negative tax shock, agents will increase their consumption. This asymmetric response of consumption can then be a potential reason for asymmetric effects of output to the tax shocks.

The friction in consumption resulting into downward stickiness is a widely studied phenomenon and is referred in the literature as ratchet effect. *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 positive tax shocks) is accompanied by a proportional fall in consumption, this effect embodies household’s resistance against fall in consumption mainly due to consumption habits acquired in the past. If workers perceive the fall in income to be permanent, or if their savings are not enough to sustain their consumption habits, they would end up supplying more labor. Thus a combination of a standard neo-classical model and ratchet effect in consumption can deliver the results observed in this paper. The standard forces in the model would deliver the *standard* results in response to a negative tax shock and the ratchet effect in consumption will deliver the results that we observe in response to a positive tax shock.
5. Conclusion

In this paper, we have presented empirical evidence of asymmetric responses of output to positive and negative R & R (exogenous and permanent) tax shocks. In particular, we find negative tax shocks to have persistent and significantly positive effect on output growth while positive tax shocks have no systematic effect on output growth. Furthermore, similar results are found when we employ positive and negative unanticipated R & R tax shocks. In addition, the asymmetry of aggregate output growth is mostly driven by individual income tax shocks. Lastly, the main result is not driven by the size of positive and negative tax shocks.

We also compute impulse responses of other important macroeconomic variables. We find that the asymmetric responses of output growth is mainly driven by asymmetric response of consumption. Investment response is symmetric. We suggest that a theory of ratchet effect in consumption - consumption goes up when taxes increase and consumption remains unchanged when taxes decrease - is one possible way to reconcile our empirical result in a theoretical framework.

Although our study is limited to long run average effects of these tax shocks on output growth, nevertheless our empirical results have at least three important consequences for long run fiscal policy: First, the empirical evidence of asymmetric effect on output growth of positive and negative tax shocks, speaks to the issue of whether tax changes are a powerful fiscal tool or not. Our results indicate that only negative tax shocks are potent insofar as stimulating the output growth. Second, the asymmetric effect on output growth is primarily stemming from the asymmetric effect of tax shocks on consumption (and not investment). Therefore, our results also suggest that a tax reduction policy with an aim of stimulating consumption growth, is much more effective than a tax reduction policy aimed to stimulate investment growth. Lastly, very small reductions in taxes are less effective in stimulating output growth. Tax authorities, with a specific goal of stimulating the economy should therefore consider both the size and the sign of the tax shock when designing a tax policy.
Studies that focus on total tax changes, without considering the asymmetric effects of positive and negative tax shocks, therefore mask this important asymmetry. However, the empirical evidence of asymmetric effect of tax shocks on output growth presented in this paper can be employed to formulate more effective and potent tax policies.
6. Acknowledgments

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A. Appendix


1. Estimate the following equation for a particular type of tax shocks. Collect the estimated coefficients for the equation and also the residuals $\epsilon_t$.

$$\Delta y_t = \alpha + \sum_{p=0}^{M} \beta_p^+ \tau_{t-p}^- + \sum_{n=0}^{M} \beta_n^- \tau_{t-n}^- + \sum_{l=0}^{L} \beta_l \Delta y_{t-l} + \epsilon_t \quad (4)$$

2. Pick a history, $\Omega_{t-1}$, 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, $\Omega_{t-1}$, and the sequence of shocks, simulate $H$ values of $y_t$. These values are simulated by using equation 4. Call this time path $y_{t+j}^n$, $j = 1, 2, ..., H$.

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 $\tau_{t+1}^+$ will be set equal to $\delta$. Values of all $\tau_{t+j}^+$ such that $j = 2, 3, ..., H$, estimate the time path of $y_t$ for this new sequence of shocks and call it $y_{t+j}^s$ 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

\[20\] Note that when impulse responses are estimated using equation (4), the value of $H$ cannot be bigger than $M$ since the effect of tax shocks only last for $M$ periods.
obtain the impulse response of $y_t$ to a shock size of $\delta$ conditional on history $\Omega_{t-1}^i$. This impulse response of $y_t$ can be represented as

$$IRF(h, \delta, \Omega_{t-1}^i) = \sum_{k=1}^{N} \frac{y_t^s(h, \delta, \Omega_{t-1}^i, k) - y_t^{ns}(h, \Omega_{t-1}^i, k)}{N}$$

where $y_t^{ns}(h, \Omega_{t-1}^i, k)$ represents the computed value of $y_t$ from step 4 at $h^{th}$ horizon. $y_t^s(h, \delta, \Omega_{t-1}^i, k)$ 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 $\Omega_{t-1}^i$ selected in step 2. $k = 1, 2, ..., N$ such values are computed through steps 4 and 5.

7. Finally, average $IRF(h, \delta, \Omega_{t-1}^i)$ 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

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

8. Use wild bootstrap $M$ number of times to compute standard errors for the computed impulse responses by repeating steps 1-7 for each bootstrapped data set.
A.2. Data Sources

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>Unanticipated tax shocks</td>
<td>Mertens and Ravn (2012a)</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.
A.3. Figures

Figure 1: R & R Tax Changes

Notes: Figure 1 illustrates the frequency, magnitude and timings of a positive and a negative Romer and Romer (2010) tax change. Each tax change is permanent and exogenous. For short we call these tax shocks as R & R tax shocks. Source: Romer and Romer (2010)

Figure 2: Cyclically-adjusted-tax-revenue Changes

Notes: Figure 2 illustrates the frequency, magnitude and timings of a positive and a negative cyclically-adjusted-tax-revenue change. Source: Romer and Romer (2010)
Figure 3: Unanticipated R & R Tax Changes

Notes: Figure 3 illustrates the frequency, magnitude and timings of a positive and a negative Romer and Romer (2010) unanticipated tax change. Note that the tax changes are different from Mertens and Ravn (2013) since these are permanent and exogenous tax changes only. For short, we call these tax shocks Unanticipated R & R tax shocks. Source: Romer and Romer (2010) & Mertens and Ravn (2011)

Figure 4: Individual Income Tax Changes (R & R)

Notes: Figure 4 illustrates the frequency, magnitude and timings of a positive and a negative Romer and Romer (2010) individual income tax change. Note that these tax changes are different from Mertens and Ravn (2013) since these are permanent and exogenous tax changes only. Source: Romer and Romer (2010) & Mertens and Ravn (2013)
Figure 5: Corporate Income Tax Changes (R & R)

Notes: Figure 5 illustrates the frequency, magnitude and timings of a positive and a negative Romer and Romer (2010) corporate income tax change. Note that these tax changes are different from Mertens and Ravn (2013) since these are permanent and exogenous tax changes only. Source: Romer and Romer (2010) & Mertens and Ravn (2013)
Notes: Figure 6 plots impulse responses of output growth to a negative and a positive Romer and Romer (2010) exogenous and permanent tax shocks in panel 1 and 2 respectively. Each plot illustrates impulse responses based on linear methodology (illustrated by a bold blue line) and non-linear methodology (illustrated by a bold red line). Computation of impulse responses from linear methodology are based on Equation 2 and non-linear methodology are based on the methodology by Kilian and Vigfusson (2011) (See Section 3 and Appendix A.1 for more detail on the methodology). The non-linear 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 growth (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 growth (output) were simulated using the coefficients estimated through a regression of real GDP growth on 12 lags of a negative and a positive tax change. 1 standard deviation confidence intervals are also provided for each of the impulse responses.
Figure 7: Impulse responses: *Cyclically Adjusted* Negative and Positive Tax Shocks

![Impulse responses: Cyclically Adjusted Negative and Positive Tax Shocks](image)

Notes: Figure 7 plots impulse responses of output growth to a negative and a positive cyclically adjusted tax shock, respectively. Each plot illustrates impulse responses based on non-linear methodology by Kilian and Vigfusson (2011) (See Section 3 and Appendix A.1 for more detail on the methodology).

Figure 8: Impulse responses: Negative and Positive *Unanticipated* R & R Tax Shocks with Anticipated Tax Change as a Control

![Impulse responses: Unanticipated R & R Tax Shocks with Anticipated Tax Change as a Control](image)

Notes: Figure 8 plots impulse responses of output growth to a negative and a positive *unanticipated* R & R tax shock, respectively. Unanticipated tax shocks are identified using Mertens and Ravn (2011)’s methodology. Each plot illustrates impulse responses based on the non-linear methodology by Kilian and Vigfusson (2011) (See Section 3 and Appendix A.1 for more detail on the methodology).
Figure 9: Impulse responses: Negative and Positive Individual Income Tax shocks

Notes: Figure 9 plots impulse responses of output growth to a negative and a positive individual income tax shock, respectively. Individual income tax shocks are identified using Mertens and Ravn (2013)’s methodology. Each plot illustrates impulse responses based on a non-linear methodology by Kilian and Vigfusson (2011) (See Section 3 and Appendix A.1 for more detail on the methodology).

Figure 10: Impulse responses: Negative and Positive Corporate income Tax shocks

Notes: Figure 10 plots impulse responses of output growth to a negative and a positive corporate income tax shock, respectively. Corporate income tax shocks are identified using Mertens and Ravn (2013)’s methodology. Each plot illustrates impulse responses based on the non-linear methodology by Kilian and Vigfusson (2011) (See Section 3 and Appendix A.1 for more detail on the methodology).
Figure 11: Impulse responses: Various Sizes of Positive and Negative Tax shocks

Notes: Figure 11(a) and Figure 11(b) plot impulse responses of output growth to a negative and a positive R & R tax shock of sizes $0.25 \times STD$, $1 \times STD$, $2 \times STD$, $5 \times STD$, $10 \times STD$ and $20 \times STD$, respectively. Each plot illustrates impulse responses based on the methodology by Kilian and Vigfusson (2011) (See Section 3 and Appendix A.1 for more detail on the methodology). The non-linear 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 growth (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 growth (output) were simulated using the coefficients estimated through a regression of real GDP growth on 12 lags of a negative and a positive tax change. 1 standard deviation confidence intervals are also provided for each of the impulse responses.
Figure 12: Impulse response of macroeconomic variables: Total Positive R & R tax measures

Notes: Figure 12 presents the effect of positive tax changes on various macroeconomic variables. The impulse responses are from a 4 variable VAR with real GDP growth, the variable, positive tax change variable, and negative tax change variable appearing in that order in the VAR. The dashed lines represent the one standard error bands.
Figure 13: Impulse response of macroeconomic variables: Total Negative R & R tax measures

Notes: Figure 13 presents the effect of positive tax changes on various macroeconomic variables. The impulse responses are from a 4 variable VAR with real GDP, the variable, positive tax change variable, and negative tax change variable appearing in that order in the VAR. The dashed lines represent the one standard error bands.