Online Appendix: Asymmetric Effects of Exogenous Tax Changes*

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1. Online Appendix

1.1. Anticipated versus Unanticipated Tax changes

Comparing our estimates with the estimates from Mertens and Ravn (2011) is not straightforward because, the tax-change series and the methodology used in the current paper differ from theirs (see Section 2 and 3). To facilitate comparison, we also employ Mertens and Ravn's (2011) specification but with both sign-based anticipated and unanticipated tax changes. We present these results in Figure 1 and Figure 2.

The main idea is that our results from anticipated and unanticipated tax decrease are qualitatively but not quantitatively comparable to Mertens and Ravn's results. Note, Mertens and Ravn's results are based on the specification that does not distinguish between the sign of the tax changes, therefore, their results can be thought of as an aggregate effect of non-sign based tax changes on macroeconomic variables. However, when we distinguish between the sign, we show that quantitatively a much bigger effect is present with an unanticipated tax decrease and an insignificant effect is present with an unanticipated tax increase. This comparison as well as our results make economic sense because, if the tax change is anticipated, the economy will make the adjustments over time and at the implementation date

*All section and appendix references in this online appendix can be found in the main paper.

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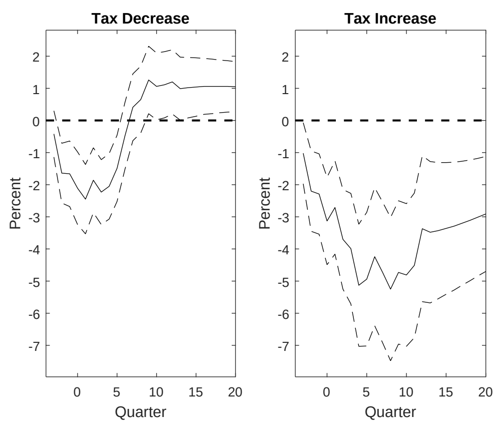
there will not be large effects on output. In contrast, unanticipated tax changes should in principle, have a much bigger effect on output as no prior change in behavior is present that can dampen the effect on output. This is what we see with the unanticipated tax decreases. However, what is surprising is that with anticipated tax increases, output shows significant negative effect for the entire horizon while for unanticipated tax increases the effect on output is insignificant.

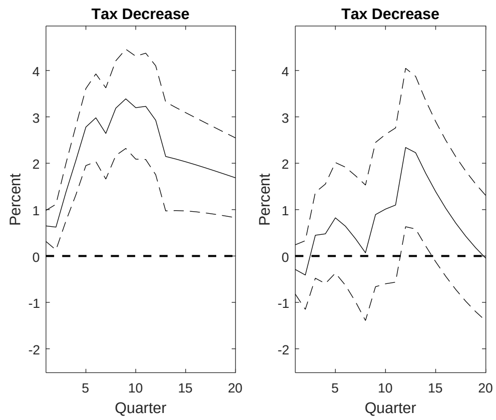
This is exactly why we explore the transmission mechanism presented in Section 5 and Section 6 to rationalize the surprising lack of significant impact of tax changes on output after an unanticipated tax increase.

Figure 1: Linear Impulse Response of Output: Anticipated Tax changes



Notes: Figure 1 plots impulse responses of output to an anticipated R & R tax decrease and increase using Mertens and Ravn (2011) specification with both sign-based tax changes.

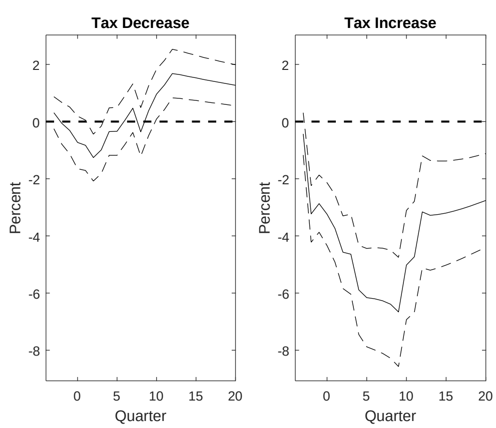
Figure 2: Linear Impulse Response of Output: Unanticipated Tax changes



Notes: Figure 2 plots impulse responses of output to an anticipated R & R tax decrease and increase using Mertens and Ravn (2011) specification with both sign-based tax changes.

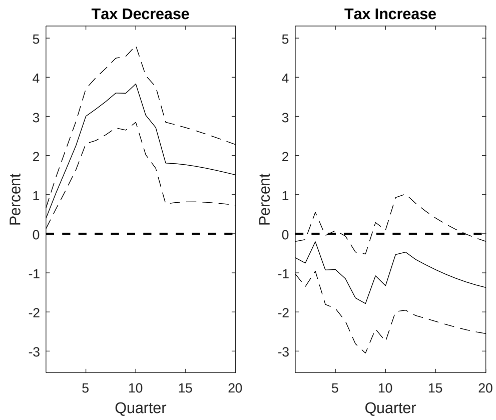
For completeness, we also provide the impulse-responses for consumption and investment in Figure (3 – 6), respectively. These results also show that anticipated positive tax changes have an effect on consumption while unanticipated positive tax change shows no effect on consumption. However, with investment we see significant negative effect with unanticipated positive tax changes as well (at least for the later part of the horizon).

Figure 3: Linear Impulse Response of Consumption: Anticipated Tax changes



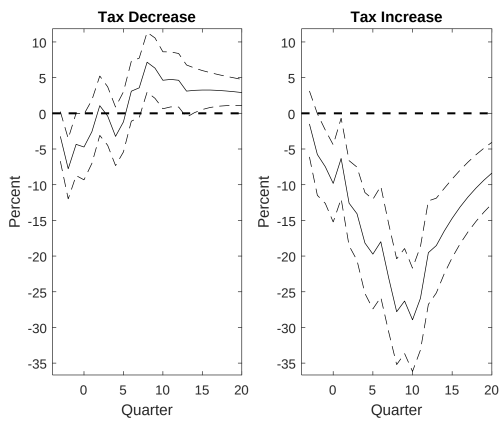
Notes: Figure 3 plots impulse responses of consumption to an anticipated R & R tax decrease and increase using Mertens and Ravn (2011) specification with both sign-based tax changes.

Figure 4: Linear Impulse Response of Consumption: Unanticipated Tax changes



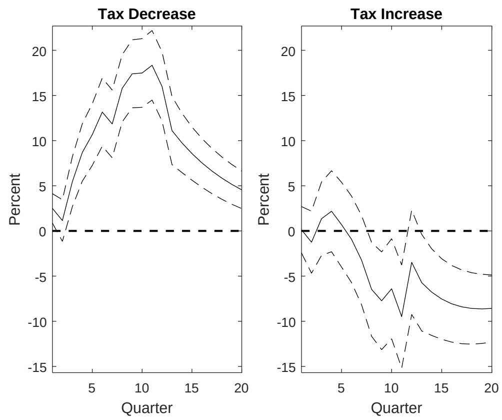
Notes: Figure 4 plots impulse responses of consumption to an anticipated R & R tax decrease and increase using Mertens and Ravn (2011) specification with both sign-based tax changes.

Figure 5: Linear Impulse Response of Investment: Anticipated Tax changes



Notes: Figure 5 plots impulse responses of investment to an anticipated R & R tax decrease and increase using Mertens and Ravn (2011) specification with both sign-based tax changes.

Figure 6: Linear Impulse Response of Investment: Unanticipated Tax changes



Notes: Figure 6 plots impulse responses of investment to an anticipated R & R tax decrease and increase using Mertens and Ravn (2011) specification with both sign-based tax changes.

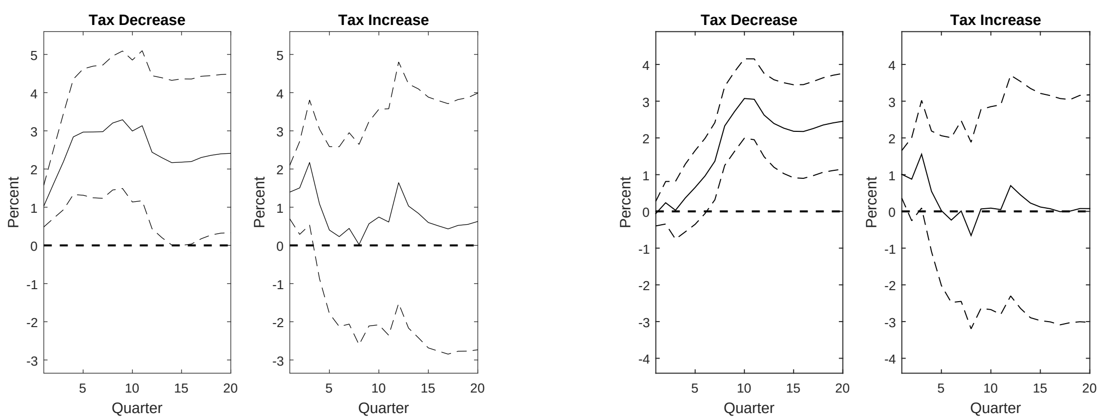
1.2. Size Asymmetry and Output Responses

Prior results and the estimation of impulse responses are based on a 1% increase and decrease in tax changes. However, on average, in our R & R tax changes, tax decreases are much larger than tax increases. If a tax change has to be of a certain size before eliciting a significant response of output, then the sign-based asymmetric responses of output from Section 4.1, might in fact be confounded with the size-based asymmetric effects of the tax changes on output.

To disentangle the differential effect of tax changes on output due to the size and the sign of tax change, we employ three approaches. In the first approach, we replace the large tax decreases, such as the Kennedy-Johnson tax cuts and the Reagan tax cuts with zero in our R & R tax change data, and compute the corresponding non-linear impulse responses. In the second approach, we use cyclically-adjusted-tax-revenue (CATR) changes as an alternative tax change measure and compute the non-linear impulse responses. In the third approach, we vary the size of the initial tax change with which we shock our dynamic system. This approach allows us to explore if the output response to an initial large tax change is more than proportional to the output response to an initial small tax change. Figure 7, Figure 8, and Figure 9 illustrate the results based on these three approaches, respectively.

The first approach exhibits long-run effects of tax decreases that are similar to the effects from original R & R tax decreases; however the computed standard errors of the impulse responses are bigger yet significantly different from zero for almost all the quarters. The response of output to tax increases is again highly insignificant throughout the horizon. The differential effects of sign-based tax changes are robust to this alternative tax-change measure which is constructed by replacing the large tax cuts by zeros. Note that the impulse responses of output to tax increases in Figure 7(a) and Figure 7(b) differ from each other despite the fact that the tax-increase series is the same for both impulse responses. This difference in the impulse responses highlights that the impulse responses in this paper are computed by controlling for the possible history of tax changes. Because the series of tax decrease used in approach one is different, the impulse responses are averaged across different histories. Comparing Figure 7(a) and Figure 7(b), we conclude that the concerns about large tax cuts in our tax measure do not drive the asymmetric responses of output to sign-based tax changes.

Figure 7: Impulse Responses: Various Sizes of Tax Increase and Tax Decrease



(a) Impulse Responses - Excluding large R & R tax decreases

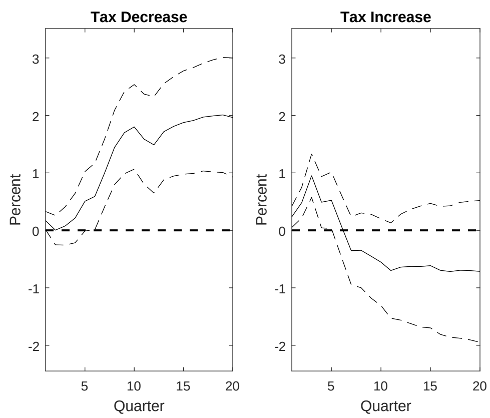
(b) Impulse Responses: R & R tax changes

Notes: Figure 9 plots impulse responses of output to a sign-based R & R tax change. Figure 7(a) illustrates the impulse responses of output to a tax-change series which excludes four large tax cuts namely, the Truman tax change, the Kennedy-Johnson tax change, the Reagan tax change, and the Nixon tax change. Figure 7(b) illustrates the impulse responses of output to an original R & R tax-change series (that contains all exogenous, permanent tax changes). Each plot illustrates impulse responses based on the methodology by Kilian and Vigfusson (2011) (see Section 3 and Appendix A.2 for more detail on the methodology).

The second approach uses CATR changes which, in contrast to R & R tax changes, have on average smaller size of tax decreases than tax increases. Despite the potential issue with these tax changes, the exercise with these tax changes allow us to explore if our key result is driven because of asymmetric size of sign-based tax changes in R & R data. Romer and Romer (2010) also use these nominal tax revenues normalized by a chain-type price index of GDP. To facilitate the comparison of these tax changes with R & R tax changes, Romer and Romer (2010) also compute the change in the real cyclically-adjusted-tax-revenues normalize by real GDP.

Figure 8 illustrates the computed response of output to a sign-based cyclically-adjusted-tax-revenue change series. We find that the results are qualitatively similar to the results from R & R tax changes. The estimated implied effect of a decrease in CATR on output is about 2.3%, whereas an increase in CATR has an insignificant effect on output. This reassures that the key finding of asymmetric responses of output to sign-based tax changes is not driven by size-based asymmetry in R & R tax decrease and increase.

Figure 8: Impulse Responses: Cyclically-Adjusted Tax Decrease and Increase



Notes: Figure 8 plots impulse responses of output to a sign-based cyclically adjusted tax change, respectively. Each plot illustrates impulse responses based on non-linear methodology by Kilian and Vigfusson (2011) (see Section 3 and Appendix A.2 for more detail on the methodology).

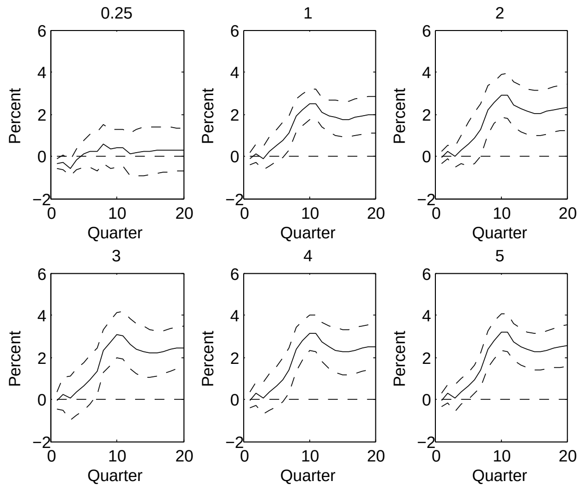
In the third approach, instead of using a 1% change in tax measure, we measure the size of tax changes in terms of the standard deviation of the tax changes, such that a tax change of size 1 corresponds to one standard deviation of a tax increase and a tax change of size -1 corresponds to one standard deviation of a tax decrease. In terms of the non-linear methodology explained in Section 3.2 and the corresponding step-by-step explanation of the methodology in Appendix A.2, we vary the size of the initial tax change denoted by δ. In particular, while simulating the time path of output for various sizes of tax changes, we replace the first value of the tax change sequence with $\delta\sigma_{tax}$, where

$$\delta \in \pm\{0.25, 1, 2, 3, 4, 5\},$$

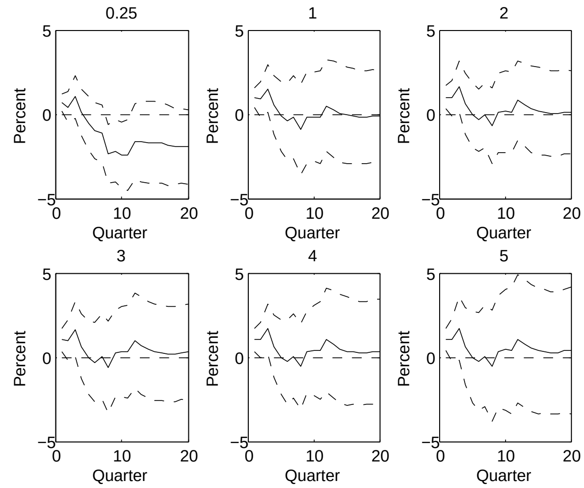
and σ_{tax} is the standard deviation of the R & R tax changes.[1]

[1]Note that some of the sizes of tax changes considered for this analysis are either rarely observed or have little identifying variation in the data. Therefore, estimating the effect of a particular size of a tax change on output with any precision is impossible if we take a subset of the data corresponding to the size of tax changes. However, we only replace the first value of the tax change of interest with a tax change of size $\delta\sigma_{tax}$, while the rest of the sequence of the tax changes are drawn from the original data. Variation in the size of the initial tax change then affects the time path of output. Subsequently, the difference between this time path of output and the time path of output in which the first value of tax change is not varied then provides the relative effect on the output path due to the size of the tax change. We then normalize the difference

Figure 9: Impulse Responses: Various Sizes of Positive and Negative Tax changes



(a) Non-linear impulse response of output: For various sizes of R & R tax decreases



(b) Non-linear impulse response of output: For various sizes of R & R tax increases

Notes: Figure 9(a) and Figure 9(b) plot impulse responses of output to a R & R tax decrease and increase of size $0.25 * STD$, $1 * STD$, $2 * STD$, $3 * STD$, $4 * STD$ and $5 * STD$, respectively. Each plot illustrates impulse responses based on the methodology by Kilian and Vigfusson (2011) (see Section 3 and Section A.2 for more detail on the methodology). The non-linear impulse responses are the 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 changes 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 δ, where δ was the size of the change 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 sign-based tax change. One standard-deviation confidence intervals are also provided for each of the impulse responses.

The impulse responses are illustrated in Figure 9. The impulse responses are all normalized by the size factor, which is $\delta\sigma_{tax}$. Corresponding to the normalized impulse responses, we also compute bootstrapped standard errors. Two main results are evident. First, in general, initial tax increase of any size consistently results in an insignificant effect on output. The magnitude of output responses to an initial *small* tax increase is mostly insignificant, but the effect is much bigger than the effect from initial *large* tax increase. Second, tax decreases in general have a significant effect on output for various sizes of initial tax changes. More importantly, the effect of various sizes of initial tax decreases on output is almost proportional to the size of the initial tax change, which confirms that the asymmetric effect on output observed in Section 4.1 is not an outcome of the size of a tax decrease. Interestingly, we also find that relative to large (initial) tax decreases, small tax decreases (i.e., tax changes of size < 1 standard deviation) have an almost insignificant impact on output (just as we observed for the output responses to tax increases).

The results from the three approaches jointly reaffirm that the size of the tax change does not drive the asymmetric response of output following a sign-based tax change.

by the size of the tax change to infer whether the effect of the size of the tax change has a proportional or more than proportional effect on output.

1.3. Robustness Exercise

This section provides a robustness check for our key result of asymmetric output responses to exogenous sign-based tax changes, by using an alternative methodology that utilizes a two-equation specification to *exactly* match the framework provided by Kilian and Vigfusson (2011). In the text, instead of two-equation model, we use a single-equation model because single-equation specification generalizes the regression approach pioneered by Romer and Romer (2010) and facilitates comparison across the two studies. The main purpose of this exercise is to show that the two methodologies are quantitatively and qualitatively exactly the same.

1.3.1. Steps for Computation of Impulse Response and Standard Errors:

1. Estimate the following equations. Collect the estimated coefficients for the equation and the residuals:

$$\Delta\tau_t = \alpha_1 + \epsilon_{1t} \tag{1}$$

$$\Delta y_t = \alpha_2 + \sum_{p=0}^{M} \beta_p^{+} \Delta\tau_{t-p}^{+} + \sum_{n=0}^{M} \beta_n^{-} \Delta\tau_{t-n}^{-} + \sum_{l=0}^{L} \beta_l \Delta y_{t-l} + \epsilon_{2t}, \tag{2}$$

   Note that a tax change is denoted with $\Delta\tau_t$, which is the series provided by Romer and Romer's 2010 narrative data.

2. Estimate $\Delta\tau_t$ using ϵ_{1t} via Equation 1 and then define the following:

$$\Delta\tau_t^{+} = max(0, \Delta\tau_t), \qquad \Delta\tau_t^{-} = min(0, \Delta\tau_t). \tag{3}$$

   Note that the estimated values of $\Delta\tau_t$ series match $\Delta\tau_t$ provided by the data. Therefore, under this two-equation model and the single-equation model (provided in Section 3), the sign-based tax changes are also exactly the same.

3. Pick a history, Ω_{t-1}^{i}, which consists of a block of M consecutive values of all model variables. These are actual values from the data series. The values drawn for all the variables should be for the same dates.

4. Choose a sequence of H values of the residual ϵ_{1t} and ϵ_{2t} with replacement from the residuals collected after the initial estimation.

5. Using the history, Ω^i_{t-1}, and ϵ_{1t}, simulate H values of y_t. These values are simulated by using equation 2. Call this time path $y^{ns}_{t+j}, j = 1, 2, ..., H$. Note that $\epsilon_{1t} = \Delta\tau_t - \bar{\Delta\tau_t}$; therefore, it is a linear transformation of $\Delta\tau_t$.

6. Repeat step 4 with one change. In the ϵ_{1t} sequence, replace the first value with a constant value δ and estimate the time path of y_t for this new sequence of tax changes and call it y^s_{t+j}, where $j = 1, 2, ..., H$.

7. Take the difference of the two simulated paths. Repeat steps 3 through 5 N times and collect N such series. Average the resulting series to obtain the impulse response of y_t to a tax change (i.e., ϵ_{1t}) of size δ *conditional* on history Ω^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 tax change of size δ for history Ω^i_{t-1} selected in step 2. $k = 1, 2, ..., N$ such values are computed through steps 4 and 5.

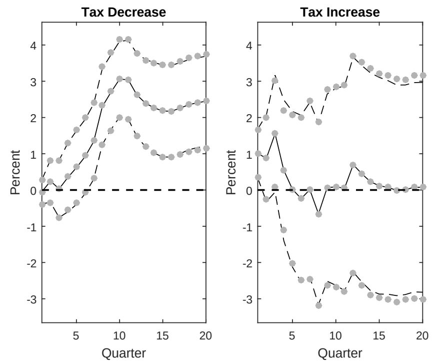
8. Finally, average $IRF(h, \delta, \Omega^i_{t-1})$ over all histories to obtain the non-linear impulse response of y_t to a tax change of size δ. This impulse response can be represented as

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

9. Residuals from the estimated dynamic regression models involving daily, weekly, and monthly data exhibit a strong evidence of conditional heteroskedasticity. Therefore, standard errors based on the standard residual-based bootstrapped method may be invalidated in the presence of such heteroskedasticity. To guard against the presence of heteroskedasticity, we follow the wild bootstrap methodology as proposed by Goncalves and Kilian (2004). In particular, we use wild bootstrap M times to compute standard errors for the computed impulse responses by repeating steps 1-7 for each bootstrapped data set. We then use these standard errors to construct 95% confidence intervals.

Below, we present the impulse responses using a single-equation model and two-equation model to show that the two approaches provide the same results.

Figure 10: Non-Linear Impulse Response of Output: Single-Equation and Two-Equation Model



Notes: Figure 10 plots impulse responses of output to a R & R tax increase and decrease for single-equation model (gray plot) and two-equation model (black plot). Each plot illustrate impulse responses based on the general methodology by Kilian and Vigfusson (2011) (see Section A.2 and Section 1.3.1 for more detail on the methodology based on single-equation and two-equation model, respectively). The non-linear impulse responses are the 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 output growth, one in which the tax changes 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 δ, where δ is the size of the tax change given as a shock to the dynamic system. The paths for real output growth were simulated using the coefficients estimated through a regression of real output growth on 12 lags of a tax decrease and a tax increase. One standard-deviation confidence intervals are also provided for each of the impulse responses.

References

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