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When are tax multipliers large? ☆

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ABSTRACT

I show that the US tax multiplier depends on the direction of the tax change. The tax multiplier is significantly larger (in absolute value) for tax hikes than for tax cuts – regardless of whether I identify tax shocks via (i) the narrative approach or (ii) sign restrictions. The tax hike multiplier is strongly pro-cyclical, i.e., substantially larger in expansions. Variation in the tax cut multiplier over the business cycle is milder and statistically insignificant. A simple business cycle model with downward nominal wage rigidities can explain these results.

1. Introduction

The effects of a change in tax policy on output are of key importance for fiscal and stabilization policy considerations. In particular, it is often argued that tax cuts boost output when the economy is operating below potential, while tax hikes help to stop the economy from overheating. While a large literature estimates the US tax multiplier in a linear framework,[1] recent evidence points to the possibility that tax multipliers are smaller when the economy is doing poorly.[2] In this paper, I show that an important but so far little appreciated determinant of the tax multiplier is the direction of the tax change.

Using the two main identification strategies in the literature, I study whether tax hikes and tax cuts have asymmetric effects on output and whether the effects of tax cuts and/or tax hikes vary over the state of the business cycle. To allow for asymmetric and state-dependent tax multipliers, I follow Barnichon et al. (2021), who estimate asymmetric and state-dependent government spending multipliers and use the Functional Approximation of Impulse Responses (FAIR) method. The FAIR method directly estimates the data's structural moving average representation (SVMA). To make the estimation of non-linear models feasible, it reduces the number of parameters by imposing a strong dynamic restriction on the impulse responses. Specifically, it assumes that the impulse responses can be approximated by a few Gaussian basis functions. Thanks to these characteristics, FAIR allows to study the asymmetric and state-dependent effects of tax hikes and tax cuts in combination with the two leading identification strategies in the literature: (i) an instrumental variable approach based on a narrative measure of tax shocks (Romer and Romer, 2010); (ii) an approach based on sign restrictions on the impulse responses to tax shocks (Mountford and Uhlig, 2009). The two identification strategies rest on non-overlapping assumptions, and considering both may help identify a robust set of results.

☆ An earlier version of the paper circulated under the title "Can tax cuts restore economic growth in bad times?".
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[1] See Blanchard and Perotti (2002), Mountford and Uhlig (2009), Romer and Romer (2010), Barro and Redlick (2011), Favero and Giavazzi (2012), Perotti (2012), Mertens and Ravn (2014), Caldara and Kamps (2017), among others.

[2] See for instance, Candelon and Lieb (2013), Peren Arin et al. (2015), Eskandari (2019), Ghassibe and Zanetti (2022).

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I find that the US tax multiplier is strongly asymmetrical in the direction of the tax change. The tax hike multiplier — the tax multiplier associated with a tax hike — is about three times larger than the tax cut multiplier, and the difference is highly statistically significant. I also find that the tax hike multiplier is substantially larger (in absolute value) when economic slack is low. The tax cut multiplier varies less (and statistically insignificantly) over the state of the economy. While still sizeable, the gap between the tax hike and tax cut multiplier thus narrows during recessions and widens during expansions.

My paper adds to the growing literature on the state-dependent effects of tax changes. These studies typically find that the tax multiplier is pro-cyclical and that tax changes are ineffective in recessions using either the narrative approach (Peren Arin et al., 2015; Eskandari, 2019; Ghassibe and Zanetti, 2022) or the sign restrictions approach (Candelon and Lieb, 2013). Different from these papers, I also consider the asymmetric effects of tax hikes and tax cuts, and my results indicate that (i) pro-cyclicality in the tax multiplier is primarily driven by pro-cyclical effects of tax hikes, and (ii) since the tax cut multiplier varies less over the cycle and is still statistically significant in recessions, tax cuts remain an effective stabilization tool in recessions.

Few studies have attempted to estimate the asymmetric effects of tax cuts and tax hikes. My results contrast earlier evidence based on the narrative approach indicating that the tax multiplier is larger (in absolute value) for tax cuts than for tax hikes (Jones et al., 2015; Hussain and Malik, 2016). These studies used reduced form regressions of output on the Romer and Romer (2010) measure and thus do not account for possible measurement error in the narrative series. However, Mertens and Ravn (2014) show that measurement error in the narrative series plays a decisive role for estimates of the tax multiplier: accounting for measurement error in a linear setting raises the tax multiplier from close to 1 to 3 (in absolute value). Using the narrative series as an instrumental variable for the latent tax shock, as in Mertens and Ravn (2014), my results indicate that accounting for measurement error is similarly crucial for the estimation of (asymmetric) tax hike and tax cut multipliers from the narrative approach.[3]

An advantage of the paper is that the main results do not depend on one particular identification procedure but instead hold for two identification strategies with different strengths and limitations. To the best of my knowledge, this paper is the first to use the sign restriction approach to study the asymmetric effects of tax cuts and hikes. One reason why few studies have considered tax multiplier asymmetry is methodological.

The conventional approach is to use Local Projections (Jordà, 2005).[4] However, LP can only estimate *asymmetric* impulse responses if we have an instrument for the shock, for instance, identified via the narrative approach. In addition, LP is a non-parametric impulse response estimator. This has a high cost in terms of efficiency, and therefore, LP can only allow for one non-linearity. The FAIR method addresses these issues. It directly estimates the non-linear SVMA representation, allowing me to use the narrative *and* the sign restriction approach. To make the estimation of an asymmetric and state-dependent model feasible, FAIR approximates the impulse responses with a few Gaussian functions, drastically reducing the number of parameters. I use FAIR with a one-Gaussian approximation as in Barnichon et al. (2021). The vast majority of time series studies (e.g., Mertens and Ravn, 2014; Caldara and Kamps, 2017) and DSGE models (e.g., Zubairy, 2014) report approximately monotonic tax revenue and hump-shaped output responses to tax shocks,[5] and such patterns can be well approximated with one Gaussian function (Barnichon and Matthes, 2018).[6] Naturally, the approach and its advantages are invalid if the impulse responses cannot be well approximated with a few Gaussian functions, for instance, when they exhibit multiple peaks or an oscillating pattern. In that case, the parametric assumption introduces bias, and the credible sets are less likely to include the true impulse responses. Thus, the choice between LP and FAIR involves navigating a bias-variance trade-off, i.e., LP has a lower bias but a larger variance, much like the choice between LP and VAR in a linear setting (see, Plagborg-Møller and Wolf, 2021; 2022).

To rationalize the results, I set up a simple business cycle model with downward nominal wage rigidity (DNWR) as in Schmitt-Grohé and Uribe (2016). DNWR gives rise to cyclical unemployment (when the labor market clearing wage falls below the wage floor) and generates asymmetry and state dependence in the tax multiplier. A labor income tax rate[7] affects desired labor supply and the labor market clearing wage. After a tax cut (hike), the labor market clearing wage decreases (increases). However, downward wage adjustments are constrained by DNWR, and thus wages, and in turn, employment and production react less to a tax cut than to a tax hike. In a recession, when unemployment is high, the effects of a tax change are smaller since the wage is well above the labor market clearing level. I show in a quantitative example that the model can account well for the asymmetry and state dependence in the data.

My model is highly stylized, and other mechanisms are possible. In an important recent contribution, Ghassibe and Zanetti (2022) develop a theory of state-dependent government spending and tax multipliers that rests on search frictions in the goods market. Labor search frictions also generate state-dependent government spending (Michaillat, 2014) and tax (Ziegenbein, 2017) multipliers. Ferraro and Fiori (2023) consider multiple non-linearities and show that tax hikes have larger effects than tax cuts and tax cuts have larger effects in recessions in a model with labor search frictions. While my empirical results support the predicted

[3] For instance, suppose we estimate that a 1$ increase in the narrative measure is followed by a 1$ decrease in output, while a 1$ decrease is followed by a 2$ increase in output. Ignoring possible measurement error, we conclude that the effects of a tax decrease are twice as large (in absolute value). However, now suppose that the narrative tax shock series is measured with error. Specifically, suppose that a 1$ increase in the narrative measure is followed by a 0.25$ increase in tax revenues while a 1$ reduction in the narrative measure is followed by a 1$ decrease in tax revenues. Accounting for measurement error, the results change, and we conclude that the tax hike multiplier is $-1/0.25 = -4$ while the tax cut multiplier is $-2/2 = -1$.

[4] A structural VAR representation does not exist when the impulse responses are sign-dependent (Barnichon and Matthes, 2018).

[5] Mertens and Ravn (2014) and Caldara and Kamps (2017) show VAR-based impulse responses from multiple identification strategies. Ramey (2019) summarizes the evidence from time series and fiscal DSGE models. I also provide a comprehensive list of time series studies in the online appendix.

[6] To relax the assumption and allow for more flexibility, I also estimate a model using two Gaussian functions which can capture impulse responses with an overshooting pattern or two peaks (Barnichon et al., 2022). The results remain similar, and posterior odds ratios strongly favor the smaller model.

[7] I focus on labor income taxes as they account for the bulk of federal tax revenues, i.e., 74% on average in the post-World War II sample.

asymmetric effects, I do not find evidence that the effects of tax cuts increase in recessions. This suggests other mechanisms may also be important. I consider a different labor market friction, namely downward nominal wage rigidity. The appeal of my simple model is that a single friction can account well for a large fraction of the asymmetry and state dependence in the data. Finally, my model is similar to previous studies on the state-dependent (Shen and Yang, 2018) or sign- and state-dependent (Barnichon et al., 2021) effects of government spending, but introduces flexible labor supply to allow for a role of income taxation.

The remainder of the paper is structured as follows. Section 2 introduces the empirical model, the FAIR method, and the two alternative identification strategies. Section 3 presents the asymmetric model and the results for the asymmetric tax multiplier. Section 4 extends the model to also allow for state dependence. Section 5 describes the theoretical model. Section 6 concludes.

2. Empirical model

This section introduces an empirical model designed to measure how the tax multiplier depends on (1) the direction of the intervention —i.e., tax hike or tax cut—, and (2) the state of the economy.

I consider the impulse response representation of the data, i.e., the vector moving average (VMA) model

$$\boldsymbol{y}_t = \sum_{k=0}^{K} \boldsymbol{\Psi}_k(\boldsymbol{\varepsilon}_{t-k}, z_{t-k})\boldsymbol{\varepsilon}_{t-k}, \tag{1}$$

where $\boldsymbol{y}_t$ is a vector of stationary macroeconomic variables. $\boldsymbol{\varepsilon}_t$ is a vector of structural shocks with $E(\boldsymbol{\varepsilon}_t) = 0$, $E(\boldsymbol{\varepsilon}_t\boldsymbol{\varepsilon}_t') = \boldsymbol{I}$. K is the lag order, and z_t is a stationary variable describing the state of the economy. $\boldsymbol{\Psi}_k(\boldsymbol{\varepsilon}_{t-k}, z_{t-k})$ is the impulse responses at horizon k that can depend on (a) the value of the shock $\boldsymbol{\varepsilon}_{t-k}$ – for instance, the sign of the shock – and (b) the state of the economy captured by variable z_{t-k}.

Since $\boldsymbol{\Psi}_k(\boldsymbol{\varepsilon}_{t-k}, z_{t-k})$ is a function of $\boldsymbol{\varepsilon}_{t-k}$, the impulse response can depend on the sign of the shock $\boldsymbol{\varepsilon}_{t-k}$. Here, I am primarily interested in whether tax hikes (positive tax shocks) and tax cuts (negative tax shocks) trigger different impulse responses. Since $\boldsymbol{\Psi}_k(\boldsymbol{\varepsilon}_{t-k}, z_{t-k})$ is a function of the state variable z_{t-k}, the impulse response can depend on the state of the economy.

The VMA representation is appealing for our purpose because, other than a VAR, it directly captures the impulse responses and can thus easily allow for non-linear effects of shocks. Unfortunately, the VMA representation is difficult to estimate due to the size of the parameter space. For instance, consider a typical quarterly data set with 50 years of data, i.e., 200 observations and a typical impulse response horizon of $K = 20$ quarters. Not allowing for asymmetry or state dependence, we already need to estimate 21 parameters per impulse response. Introducing asymmetry, that number doubles to 42 parameters. With asymmetry and a simple binary recession indicator, the number doubles again to 84 parameters. Such a setting does not allow to conduct inference on the sign- and state-dependent effects of tax policy in a meaningful way.

The conventional way to shrink the VMA dimension is to start from a VAR representation. Unfortunately, the VMA does not have a VAR representation when the shocks have sign-dependent effects. To avoid the issue, I use Barnichon and Matthes' (2018) Functional Approximation of Impulse Responses (FAIR). The approach relies on approximating the impulse responses —i.e., the VMA representation— via a Gaussian basis function. Thus, like a VAR, FAIR reduces the parameter space. Yet, unlike a VAR, FAIR can capture the asymmetric effects of shocks. For clarity of exposition, I briefly introduce the methodology in the next section.[8]

2.1. Functional approximations of impulse responses

To illustrate the workings of FAIR (Barnichon and Matthes, 2018), consider first a linear version of (1), i.e.

$$\boldsymbol{y}_t = \sum_{k=0}^{\infty} \boldsymbol{\Psi}_k \boldsymbol{\varepsilon}_{t-k}. \tag{2}$$

Let us denote $\psi(k)$ an element of the matrix $\boldsymbol{\Psi}_k$. That is, $\psi(k)$ is the value of the impulse response ψ at horizon k. Barnichon and Matthes (2018) propose to use a Gaussian function to approximate the impulse responses ψ:

$$\psi(k) = \begin{cases} \psi_0, & k = 0 \\ ae^{-\left(\frac{k-b}{c}\right)^2}, & \forall k \geq 0 \end{cases} \tag{3}$$

with a, b, c, and ψ_0 parameters to be estimated.[9]

A Gaussian function can provide a good approximation of monotonic or hump-shaped impulse responses while offering a drastic dimension reduction. For instance, considering $K = 20$ again, FAIR reduces the number of parameters per impulse response from 21 to 4.

Another advantage of Gaussian functions is that they are easy to interpret. Fig. 1 visualizes how the parameter a is the extremum effect of a shock, b describes the timing of the extremum effect, and c captures the persistence of the response to the shock. Specifically, $\tau = c\sqrt{ln\,2}$ describes the half-life of the extremum effect.

[8] For a detailed discussion, see Barnichon and Matthes (2018).

[9] For flexibility reasons, we treat the contemporaneous impact coefficient $\psi(0)$ as a free parameter.

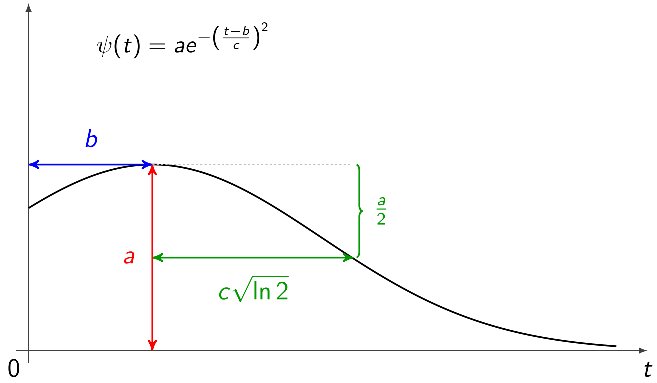


Fig. 1. Functional approximation of impulse responses (Barnichon and Matthes, 2018).

2.2. Two identification strategies

The literature has primarily followed two approaches to identify the effects of tax shocks: (ii) a narrative approach and (ii) sign restrictions on impulse responses. In this paper, I will use both identification strategies because both have important relative advantages and to establish the robustness of the main results. For simplicity, I will introduce both approaches in a symmetric setup before discussing the introduction of sign- and state-dependence.

The narrative approach

The narrative approach to identifying tax shocks pioneered by Romer and Romer (2010) and recently updated by Liu and Williams (2019) is likely the most popular in the recent past. Romer and Romer (2010) use historical sources[10] to record U.S. tax code changes along with their projected impact on federal tax liabilities and motivation. Each tax act is classified by its key purpose as either (i) spending-driven, (ii) countercyclical, deficit-driven (to reduce an inherited budget deficit), or to raise long-run growth. Romer and Romer argue that tax changes that address an inherited budget deficit or aim to increase long-run growth are *exogenous* because they are not motivated by current or short-run economic conditions. Their original series covers quarterly data from 1947 to 2007. Recently, Liu and Williams (2019) updated the series until the end of 2017, applying the same rules as Romer and Romer. The updated series contains 53 exogenous tax changes. Of those, 25 are tax cuts, and 28 are tax hikes. I treat the narrative series as an external instrument (IV). Exactly like in an internal SVAR-IV setting (see Plagborg-Møller and Wolf, 2021), FAIR-IV is carried out by ordering the instrument first and assuming the first row of $\boldsymbol{\Psi}_0$ is filled with zeros except for the diagonal coefficient (Barnichon and Matthes, 2018). Specifically, I augment a standard fiscal policy vector (see, e.g., Blanchard and Perotti, 2002, Mertens and Ravn, 2014) with the updated Romer and Romer instrument. That is, I consider a vector spanning the narrative measure ι_t, real federal tax revenues tr_t, real federal government spending g_t, and real GDP y_t, i.e., $\boldsymbol{y}_t = \left(\iota_t, tr_t, g_t, y_t\right)'$.

The sign restriction approach

An alternative approach is to identify tax shocks via sign restrictions on the impulse responses. Mountford and Uhlig (2009) suggest that a tax shock moves tax revenues and real GDP in opposing directions. For instance, a positive tax shock raises tax revenues while lowering real GDP simultaneously.[11] I consider the same vector of variables as before, now excluding the narrative measure, i.e., $\boldsymbol{y}_t = \left(tr_t, g_t, y_t\right)'$. Following Baumeister and Hamilton's (2015) recommendation, I only impose sign restrictions on the contemporaneous effects of tax shocks. That is, I only impose restrictions on $\boldsymbol{\Psi}_0$ while impulse responses at higher order $\boldsymbol{\Psi}_{k>0}$ remain unrestricted. Implementing the Mountford and Uhlig (2009) restrictions, we have

$$\boldsymbol{\Psi}_0 = \begin{pmatrix} + & x & x \\ x & x & x \\ - & x & x \end{pmatrix}$$

where x denotes an unrestricted parameter.

[10] Such as presidential speeches, the Economic Report of the President, and reports of Congressional committees.

[11] Mountford and Uhlig (2009) identify (i) a business cycle shock which requires that output and tax revenue move in the same direction and (ii) a tax revenue shock that raises tax revenues and is orthogonal to the business cycle shock. Taken together, (i) and (ii) imply that a tax shock must move tax revenues and output in opposing directions (see Caldara and Kamps, 2008).

Why two identification strategies are better than one

The two identification strategies rely on non-overlapping assumptions. I consider both to establish a robust set of results. The sign restriction approach assumes the sign of the output and tax revenue impact responses but does not require instrument validity. The narrative approach requires instrument validity, which depends on subjective judgment,[12] but instead estimates the impact responses.[13]

2.3. Estimation

I provide a brief, intuitive description of VMA-FAIR estimation before turning to the specifics. The critical step in moving average model estimation (with FAIR parametrization) is the computation of the likelihood function. We first need to truncate the model at some horizon K. The truncation error is small if we choose a large enough K and the variables in the model are stationary. The first K structural shocks $\{\epsilon_{t-k}\}_{j=-(K-1)}^{0}$ are set to zero to start the computation.[14] Assuming ϵ_t is Gaussian, we can now recursively compute the reduced form errors e_t, given a set of parameters, and calculate the log-likelihood. At this point, we can impose the identification restrictions on the impact matrix $\boldsymbol{\Psi}_0$. Like in an SVAR $\boldsymbol{\Psi}_0$ maps the reduced form errors into structural shocks, i.e., $\boldsymbol{\Psi}_0\epsilon_t = e_t$. We can either use an optimization algorithm to obtain maximum likelihood estimates or Bayesian methods to explore the posterior distribution.

More specifically, I closely follow Barnichon et al. (2022) and estimate the parameters of the truncated (at $K = 20$ quarters) VMA model with FAIR parametrization using Bayesian methods.[15] I explore the posterior density with a Metropolis-Hastings algorithm using flat (improper) priors so that we can interpret the results as outcomes of a maximum likelihood estimation.[16] I initialize the parameters reflecting no non-linearity, i.e., no asymmetry and no state dependence, consistent with the null hypothesis of the paper: tax shocks have symmetric effects on the economy.[17] Introducing identification via sign restrictions or instrumental variables in linear or non-linear FAIR models is straightforward (see Barnichon and Matthes, 2018; Barnichon et al., 2021).[18] To estimate the tax multipliers, I take 1 million draws. Regarding convergence diagnostics, I rely on the trace plots of the parameters and the log posterior. I discard the first 100,000 draws (burn-in).

2.4. The tax multiplier

This paper's key statistic of interest is the tax revenue multiplier. Following a majority of the recent fiscal literature (e.g., Mountford and Uhlig, 2009 and Ramey and Zubairy, 2018), I focus on a cumulative multiplier over H quarters

$$M_K = \frac{\sum_{k=0}^{K} \psi_y(k)}{\sum_{k=0}^{K} \psi_{tr}(k)} \tag{4}$$

where $\psi_y(k)$ and $\psi_{tr}(k)$ are the impulse responses of y and tr to a tax shock at horizon k. M_K measures by how many US-$ output changes when tax revenues increase by 1 US-$ over K quarters. We should expect M_K to be negative since the responses of tax revenues and output to a tax shock (ψ_{tr} and ψ_y) are likely of opposite sign.

2.5. Linear FAIR results

Before turning to asymmetry and state dependence, I estimate the linear FAIR model to establish a benchmark. The sample covers quarterly data from 1947q1 to 2017q4, and I truncate the VMA at $K = 20$ quarters. Following Ramey and Zubairy (2018), I re-scale all variables by lagged potential output estimated from a quartic polynomial trend for the logarithm of real GDP. Table 1 reports the multiplier M from cumulating the impulse responses over twelve quarters.

I find multipliers of $M = 2.52$ using the narrative approach and $M = 2.71$ using sign restrictions. This aligns well with the previous evidence.[19] The majority of studies following the two approaches report multipliers in the -1.5 to -3 range.[20] For instance, Perotti (2012), Mertens and Ravn (2012), and Mertens and Ravn (2014) use the narrative measure in VARs and report multipliers of -1.5,

[12] Historical records sometimes contradict each other, making judgment calls on whether a tax change is classified as "exogenous" or "endogenous" hard to avoid.

[13] In addition, the sign restriction approach requires that the endogenous variables fully account for the determinants of tax policy. The narrative approach expands the information set. It uses historical records to filter out tax changes driven by forward-looking policy or influences not in the set of endogenous variables.

[14] Alternatively, one could use the first structural shocks recovered from an SVAR. Barnichon and Matthes (2018) conduct a simulation experiment that suggests the initialization values of the first shocks have no discernible effect on the estimates.

[15] I truncate the model at a K large enough to ensure that the lag matrix coefficients $\boldsymbol{\Psi}_k$ are close to zero. Such a K exists since the variables are stationary.

[16] The results remain unchanged if I use loose priors centered around the symmetric FAIR estimates instead.

[17] Following Barnichon and Matthes (2018), I first estimate a standard VAR using OLS and calculate the moving average representation. I then search for the parameters of the FAIR model that best (sum of squared residuals) match the VAR impulse responses and use the result as a starting point.

[18] Barnichon and Matthes (2018) detail how to use instrumental variables and sign restrictions in symmetric or sign-dependent (asymmetric) VMAs with FAIR parametrization. Barnichon et al. (2021) extend the results to FAIR models with asymmetric *and* state dependent effects.

[19] I provide a summary of multiplier estimates from the time-series literature in the online appendix.

[20] Some studies estimate smaller multipliers. Notably, Favero and Giavazzi (2012) use the narrative measure in a fiscal VAR and find multipliers close to -1. Mertens and Ravn (2014) argue that the small multiplier is due to measurement error in the narrative measure.

Table 1
Tax multipliers at a glance.

	Linear M	Tax cut M^-	Tax hike M^+	Difference $P(M^+ < M^-)$
	A. Asymmetric (sign-dependent) tax multipliers			
Narrative approach	-2.52	-1.36	-3.74	$P > 0.95^{**}$
90% posterior probability	(-3.40, -1.31)	(-2.08, -0.35)	(-5.47, -1.66)	
Sign restrictions	-2.71	-1.22	-4.01	$P > 0.99^{***}$
90% posterior probability	(-3.56, -1.57)	(-2.21, -0.61)	(-5.09, -2.41)	
	B. Asymmetric and slack-dependent tax multipliers			
Narrative approach				
Low unemployment M_{Low}		-1.50	-4.28	$P > 0.95^{**}$
90% posterior probability		(-2.41, -0.38)	(-6.44, -1.81)	
High unemployment M_{High}		-1.01	-2.50	$P > 0.90^{*}$
90% posterior probability		(-2.03, -0.29)	(-4.18, -1.26)	
P ($M_{Low} < M_{High}$)		$P = 0.70$	$P > 0.95^{**}$	
Sign restrictions				
Low unemployment M_{Low}		-1.54	-4.55	$P > 0.99^{***}$
90% posterior probability		(-2.37, -0.45)	(-6.45, -2.89)	
High unemployment M_{High}		-0.87	-2.86	$P > 0.95^{**}$
90% posterior probability		(-1.41, -0.18)	(-3.96, -1.15)	
P ($M_{Low} < M_{High}$)		$P = 0.81$	$P > 0.95^{**}$	

Notes: The multiplier is the cumulative impulse response of output over the first 12 quarters divided by the cumulate impulse response of tax revenues over the first 12 quarters. Panel A: estimation from a sign-dependent (asymmetric) FAIR model. Panel B: estimation from an asymmetric and state-dependent FAIR model. Estimation using data from 1947q1 to 2017q4. Narrative approach: identification using Romer and Romer's (2010) narrative measure of exogenous changes in federal tax liabilities as an instrumental variable. Sign restrictions: identification using sign restrictions on impulse responses (Mountford and Uhlig, 2009). Low (high) unemployment denotes a de-trended unemployment rate of −1 percent (+2 percent).

−2.2, and −2.5 to −3, respectively. Using LP-IV, Ramey (2016) finds a multiplier close to −2. Romer and Romer (2010) estimate multipliers between −2.5 and −3.0 from autoregressive distributed lag models. As pointed out by Caldara and Kamps (2017) and Mertens and Ravn (2014), the two identification strategies yield similar multipliers because they imply almost identical within-quarter output elasticities of tax revenue.[21]

3. The asymmetric tax multiplier

I now allow the tax multiplier to depend on the direction of the tax change. I first introduce asymmetry in the FAIR framework and then describe the results.

3.1. Asymmetric FAIR

Denote ψ the impulse response of some variable to a tax shock. I now allow ψ to depend on the sign of the tax shock ϵ_t^{tr}:

$$\psi(k) = \psi^+(k) \times I_{\epsilon_{t-k}^{tr}>0} + \psi^-(k) \times I_{\epsilon_{t-k}^{tr}<0}, \tag{5}$$

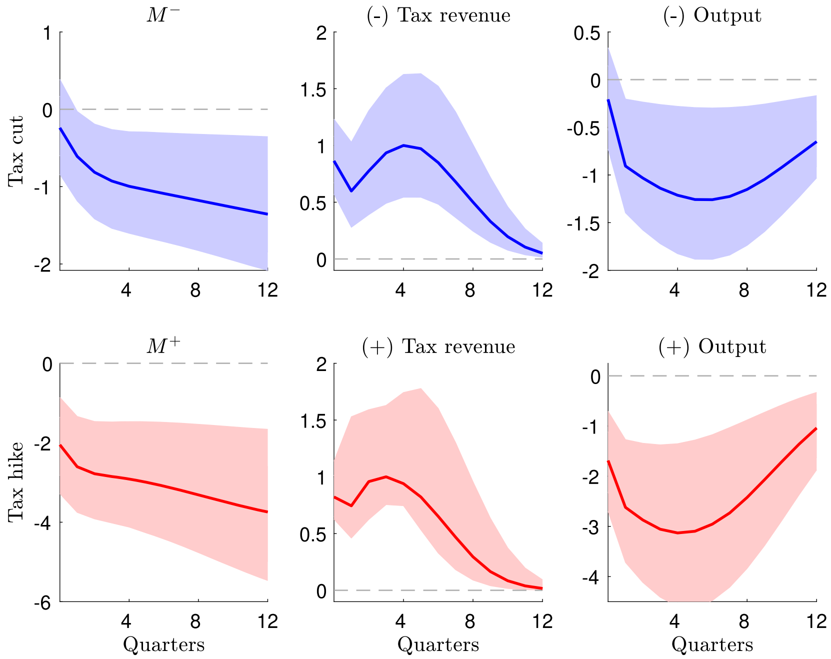
where $I_{\epsilon_{t-k}^{tr}>0}$ is an indicator variable that takes a value of 1 after a positive tax shock (tax hike) and 0 otherwise. Thus, $\psi^+(k)$ is the impulse response to a positive tax shock at horizon k. I approximate ψ^+ and ψ^- with one Gaussian function each:

$$\psi^+(k) = \begin{cases} \psi_0^+, & k = 0 \\ a^+ e^{-\left(\frac{k-b^+}{c^+}\right)^2}, & \forall k \geq 0 \end{cases} \tag{6}$$

where ψ_0^+, a^+, b^+, and c^+ are the parameters we estimate and an equivalent expression for $\psi^-(k)$. Thus, to capture an asymmetric impulse response to a tax shock, we must estimate $4 \times 2 = 8$ parameters.

I call the tax multiplier associated with a positive tax shock (tax hike) M^+ and the multiplier associated with a negative tax shock (tax cut) M^-:

[21] A direct comparison to Mountford and Uhlig (2009) is difficult because they report multipliers for policy scenarios constructed from a combination of tax and government spending shocks hitting the economy over several quarters. They obtain multipliers above three (and up to 5.3) for a *deficit financed tax cut scenario* in which tax revenues increase by exactly 1ppt for four quarters, and the government spending response is zero for four quarters.



Notes: Tax multipliers and impulse responses (in % of potential GDP) of real federal tax revenues and real GDP to a tax shock. Estimation from a sign-dependent (asymmetric) FAIR model with data covering 1947q1 to 2017q4. Identification using Romer and Romer's (2010) narrative measure of exogenous changes in federal tax liabilities as an instrumental variable. The shaded areas cover 90% over the posterior probability. To ease the comparison between the effects of tax cuts and tax hikes, the responses to a negative tax shock (tax cut) are multiplied by -1 in the top panel.

Fig. 2. Tax multipliers – FAIR with external instrument.

$$M_K^+ = \frac{\sum_{k=0}^{K} \psi_y^+(k)}{\sum_{k=0}^{K} \psi_{tr}^+(k)}, \tag{7}$$

and an equivalent expression for M_K^-.

3.2. Results from the narrative approach

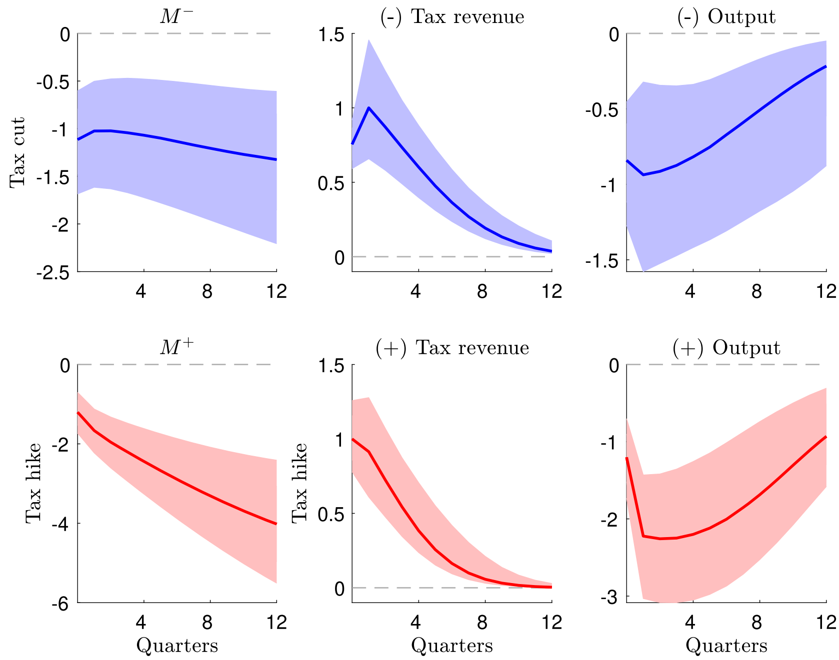
I first estimate the asymmetric FAIR-IV using the narrative measure as an external instrument. Fig. 2 plots the tax multipliers associated with a negative tax shock (tax cut, upper panel) and a positive tax shock (tax hike, lower panel). The shaded area covers 90% of the posterior probability. I find that the tax hike multiplier is larger (in absolute value) than the tax cut multiplier across all horizons. Fig. 2 and Table 1 report that cumulating the impulse response over twelve quarters, the tax hike multiplier M^+ is -3.74, and the tax cut multiplier M^- is -1.36. The evidence in favor of a sign-dependent tax multiplier is strong as the posterior probability that the tax hike multiplier is stronger than the tax cut multiplier, i.e., $M^+ - M^- < 0$, is above 0.95 (see Table 1).[22] As a reference point, Table 1 also reports that the tax multiplier M from a linear FAIR is -2.52, which is approximately the average of the large tax hike multiplier and the small tax cut multiplier.

To better understand the results, we can consider the key components of the tax multipliers, i.e., the impulse responses of output and tax revenues to a tax shock. To ease the comparison between the effects of tax cuts and tax hikes, I multiply the responses to a negative tax shock (tax cut) by -1 in the top panel. I normalize the impulse responses such that the tax revenue responses peak at 1% of potential output.[23] Note that this does not affect the tax multipliers and is only for expositional clarity.[24] We see that positive and negative tax shocks causing similar changes in tax revenue have asymmetric effects on output.

[22] To provide a more detailed picture on the difference between tax cut and tax hike multipliers, Fig. A.1 in the appendix plots the difference $M^+ - M^-$ for each horizon.

[23] I show in the online appendix that the responses of the *average* marginal labor income tax rate to tax shocks changing revenues by 1% of potential output are approximately symmetric. This suggests we compare policy interventions of similar size for tax hikes and tax cuts. Tax revenue and labor income tax rate responses are *both* symmetric if the before-tax labor income response to tax cuts and hikes are similar. That is, the sum of percent changes in total hours and average hourly wages must be similar for tax hikes and cuts.

[24] Other normalizations are possible. For example, the online appendix shows the impulse responses normalized such that the average tax rate changes by 1ppt. Importantly, the tax multiplier remains unchanged when we re-scale the output and revenue responses because it is defined as the *ratio* of the cumulated output and revenue responses.



Notes: Tax multipliers and impulse responses (in % of potential GDP) of real federal tax revenues and real GDP to a tax shock. Estimation from a sign-dependent (asymmetric) FAIR model with data covering 1947q1 to 2017q4. Identification using sign restrictions (Mountford and Uhlig, 2009). The shaded areas cover 90% over the posterior probability. To ease the comparison between the effects of tax cuts and tax hikes, the responses to a negative tax shock (tax cut) are multiplied by -1 in the top panel.

Fig. 3. Asymmetric tax multipliers – FAIR with sign restrictions.

3.3. Results from the sign restrictions approach

I now explore the asymmetry of tax multipliers using the sign restrictions approach. Fig. 3 shows the results. The sign restriction approach confirms the previous findings. The tax hike multiplier is larger (in absolute value) than the tax cut multiplier. Table 1 reports that M^+ is -4.01, and M^- is -1.36, cumulating the impulse response over twelve quarters. The evidence in favor of an asymmetric tax multiplier is again strong as the posterior probability that $M^+ - M^- < 0$ is above 0.99.[25] Again, tax cuts and hikes causing similar revenue changes lead to asymmetric output responses, and the multiplier from a linear model ($M = 2.71$) is approximately the average of the tax hike and the tax cut multiplier.

4. The asymmetric and state-dependent tax multiplier

I now allow the tax multiplier to also depend on economic slack. I first introduce state dependence in the FAIR framework and then show the results.

4.1. Asymmetric and state-dependent FAIR

To introduce state dependence in the FAIR framework, I follow Barnichon et al. (2021) and allow the extremum effect of the impulse response (a^+ and a^-) to depend on the state variable:

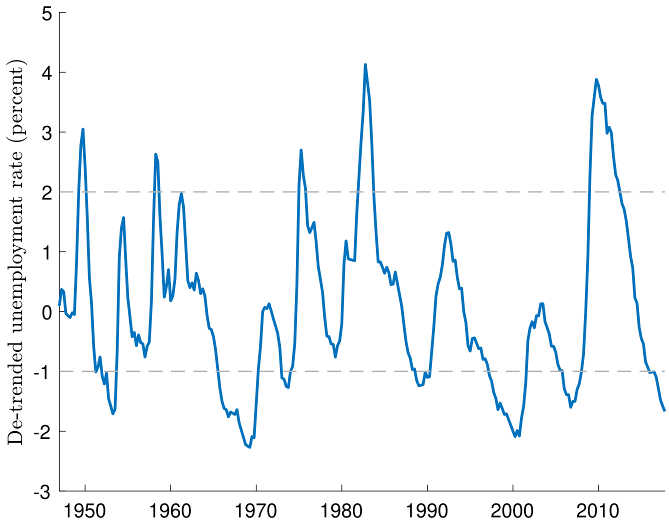
$$\psi^+(k) = a^+(z_t)e^{-(\frac{k-b^+}{c^+})^2}, \quad \forall k > 0 \tag{8}$$

and an equivalent expression for $\psi^-(k)$. I model state dependence with

$$a^+ = a_0^+ + a_1^+ z_t, \tag{9}$$

and a similar expression for a^-. We now have two parameters capturing the impulse response peak (a_0^+ and a_1^+). Thus, we must estimate $(4+1)\times 2 = 10$ parameters to capture an asymmetric and state-dependent impulse response function to a tax shock. The parameter a_1^+ governs the degree of state dependence. When $a_1^+ = 0$, the impulse response does not depend on the state variable z_t. When $a_1^+ > 0$ ($a_1^+ < 0$), a^+ increases (decreases) linearly with the state variable. The specification allows us to test whether the

[25] Fig. A.2 in the appendix plots the difference $M^+ - M^-$ for each horizon.



Notes: The de-trended unemployment rate using an HP filter with smoothing parameter $\lambda = 10^6$. The grey lines denote values of de-trended unemployment equal to $z_t = +2\%$ ("high unemployment") and $z_t = -1$ ("low unemployment").

Fig. 4. The state variable z_t.

effect of a tax cut or a tax hike depends on the level of slack in the economy. As the state variable z_t, I use the *continuous* lagged cyclical unemployment rate, shown in Fig. 4. I estimate the cyclical unemployment rate from an HP filter with smoothing parameter $\lambda = 10^6$ as suggested by Ramey (2016). Following Barnichon et al. (2021), I then compare the multiplier when unemployment is high (detrended unemployment of $z_t = 2\%$) and when unemployment is low ($z_t = -1\%$).

4.2. Results from the narrative approach

I first explore asymmetry and state dependence in the tax multiplier using the FAIR-IV approach with the Romer and Romer (2010) narrative serving as an external instrument. Fig. 5 shows the tax cut multiplier (top panels) and the tax hike multiplier (bottom panels) in a high unemployment state (detrended unemployment of 2 percent) and a low unemployment state (detrended unemployment of -1 percent). The tax hike multiplier M^+ is strongly pro-cyclical, i.e., it is larger in absolute value when the unemployment rate is low. State dependence in the tax cut multiplier M^- is milder and statistically insignificant. While the tax hike multiplier is always larger (in absolute value) than the tax cut multiplier, the gap narrows when slack is high and widens when slack is low.

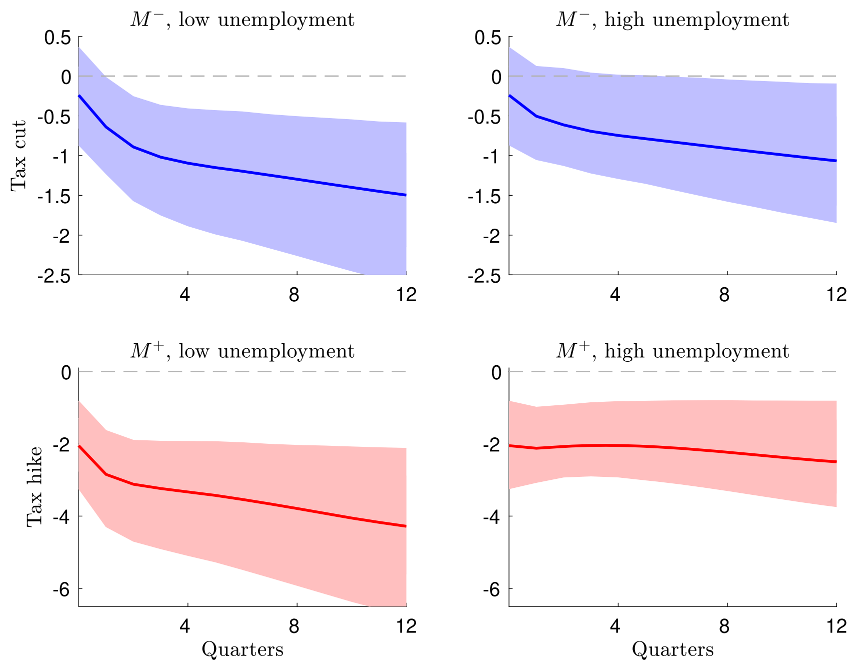
Table 1 again reports the multipliers (cumulating the impulse responses over twelve quarters) and key hypothesis tests. The tax hike multiplier is $M^+_{Low} = -4.28$ when unemployment is low and $M^+_{High} = -2.50$ when unemployment is high. Evidence in favor of state dependence in the tax hike multiplier is strong as the posterior probability that $M^+_{Low} < M^+_{High}$ is above 0.95. The tax cut multiplier is $M^-_{Low} = -1.50$ when slack is low and $M^-_{High} = -1.01$ when slack is high. The degree of state dependence in the tax cut multiplier is, therefore, weaker, and the posterior probability that $M^-_{Low} < M^-_{High}$ is only 0.70.[26] While the gap between tax hike and tax cut multiplier narrows when the unemployment rate is high, the evidence in favor of asymmetry (sign-dependence) remains strong regardless of the state of the economy. The posterior probability that the tax hike multiplier is stronger than the tax cut multiplier is above 0.95 when unemployment is low ($M^+_{Low} < M^-_{Low}$) and above 0.90 when unemployment is high ($M^+_{High} < M^-_{High}$).[27] Fig. 6 displays the effects of economic slack from a different angle and shows the impulse responses of output at three different unemployment rate levels.

4.3. Results from the sign restrictions approach

I next consider the FAIR with sign restrictions to study asymmetry and state dependence in the tax multiplier. Fig. 7 shows the tax multiplier estimates. The sign restrictions approach confirms the key results from the external instrument approach. The tax hike multiplier is substantially larger when slack is low. The tax cut multiplier varies less over the business cycle. The tax hike multiplier is always larger than the tax cut multiplier. Yet, the gap widens when slack is low and narrows when slack is high.

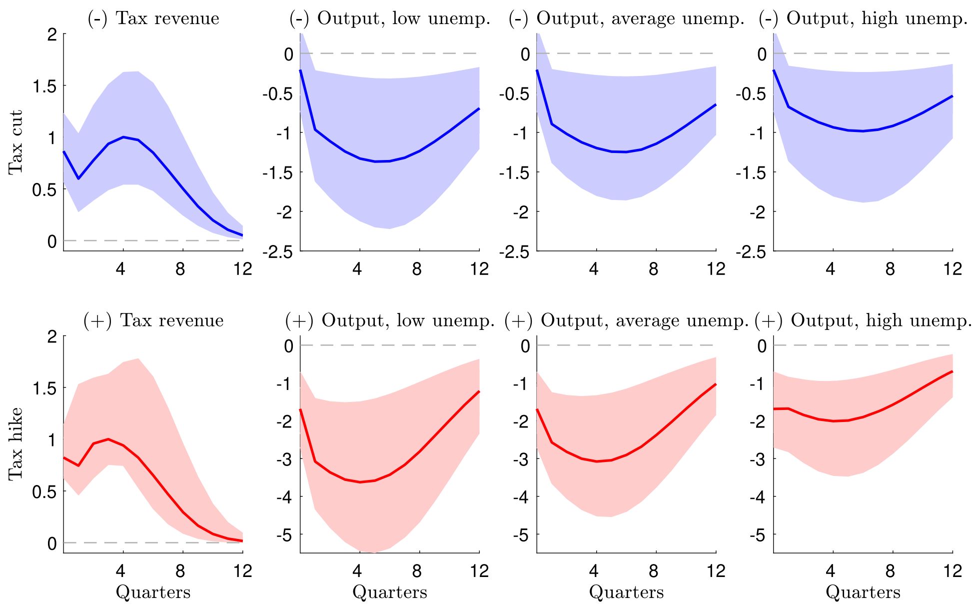
[26] Fig. A.3 in the appendix plots the difference between the low unemployment and the high unemployment multiplier for each horizon. $M^-_{Low} - M^-_{High}$ is the difference between the low slack and the high slack tax cut multiplier, while $M^+_{Low} - M^+_{High}$ is the difference between the low slack and the high slack tax hike multiplier.

[27] Fig. A.4 in the appendix plots the difference between tax hike and tax cut multiplier when unemployment is low $M^+_{Low} - M^-_{Low}$ (left panel) and when unemployment is high $M^+_{High} - M^-_{High}$ (right panel) for each horizon.



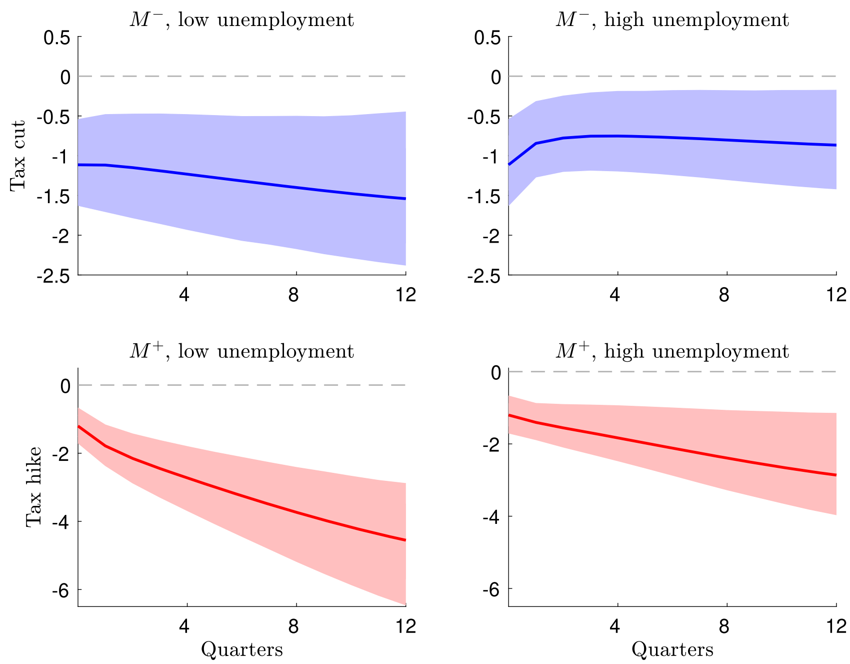
Notes: Estimation from an asymmetric and state-dependent FAIR model with data covering 1947q1 to 2017q4. Identification using Romer and Romer's (2010) narrative measure of exogenous changes in federal tax liabilities as an instrumental variable. The shaded areas cover 90% over the posterior probability. Low (high) unemployment refers to an unemployment rate 1ppt below (2ppt above) its historical average.

Fig. 5. Asymmetric and state-dependent tax multipliers – FAIR with external instrument.



Notes: Impulse responses (in % of potential GDP) of real federal tax revenues and real GDP to a tax shock. Estimation from an asymmetric and state-dependent FAIR model with data covering 1947q1 to 2017q4. Identification using Romer and Romer's (2010) narrative measure of exogenous changes in federal tax liabilities as an instrumental variable. The shaded areas cover 90% over the posterior probability. Low, average, and high unemployment denotes de-trended unemployment rates of −1, 0, and +2 percent, respectively.

Fig. 6. Asymmetric and state dependent impulse responses – FAIR with external instrument.



Notes: Estimation from an asymmetric and state-dependent FAIR model with data covering 1947q1 to 2017q4. Identification using sign restrictions (Mountford and Uhlig, 2009). The shaded areas cover 90% over the posterior probability. Low (high) unemployment denotes a de-trended unemployment rate of −1 percent (+2 percent).

Fig. 7. Asymmetric and state-dependent tax multipliers – FAIR with sign restrictions.

Table 1 again reports the twelve-quarter multipliers along with key hypothesis tests. The tax hike multiplier is $M^+_{Low} = -4.55$ when unemployment is low and $M^+_{High} = -2.86$ when unemployment is high. Evidence in favor of state dependence in the tax hike multiplier is strong as the posterior probability that $M^+_{Low} < M^+_{High}$ is above 0.95. The tax cut multiplier is $M^-_{Low} = -1.54$ when slack is low and $M^-_{High} = -0.87$ when slack is high. The evidence in favor of significant state dependence in the tax cut multiplier is, however, not strong as the posterior probability $M^-_{Low} < M^-_{High}$ is only 0.81.[28] The evidence favoring asymmetry (sign-dependence) remains strong regardless of the state of the economy. The posterior probability that the tax hike multiplier is stronger than the tax cut multiplier is above 0.99 when unemployment is low ($M^+_{Low} < M^-_{Low}$) and above 0.95 when unemployment is high ($M^+_{High} < M^-_{High}$).[29] Fig. 8 again shows how the output response gradually changes with the level of unemployment.

5. A theoretical explanation

This section provides a possible explanation for the empirical findings. I set up a New Keynesian model in which downward nominal wage rigidity generates (DNWR) as in Schmitt-Grohé and Uribe (2016) gives rise to cyclical unemployment. The model is similar to Shen and Yang (2018) and Barnichon et al. (2021) but introduces elastic labor supply, which creates a role for labor income taxation. I focus on labor income taxes as they account for the bulk of federal tax revenues[30] and to keep things relatively simple.[31]

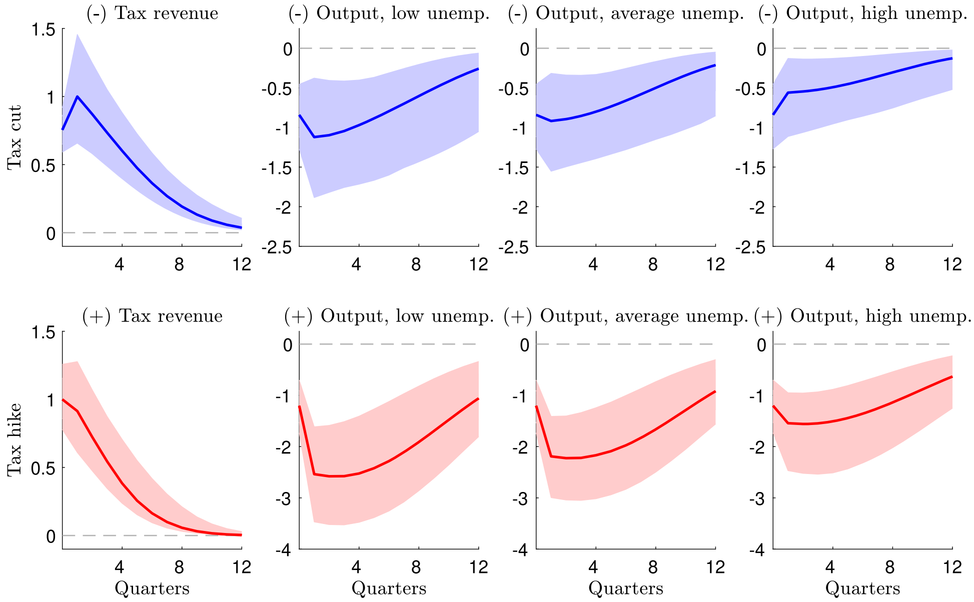
I first describe the key parts of the model (while I leave the details of the otherwise standard New Keynesian model in the appendix) and discuss intuitively how DNWR generates an asymmetric and state-dependent tax multiplier. I then simulate a calibrated version of the model to show that it can capture the empirical results well.

[28] Fig. A.5 in the appendix plots the difference between the low unemployment and the high unemployment multiplier for each horizon. $M^-_{Low} - M^-_{High}$ is the difference between the low slack and the high slack tax cut multiplier, while $M^+_{Low} - M^+_{High}$ is the difference between the low slack and the high slack tax hike multiplier.

[29] Fig. A.6 in the appendix plots the difference between tax hike and tax cut multiplier when unemployment is low $M^+_{Low} - M^-_{Low}$ (left panel) and when unemployment is high $M^+_{High} - M^-_{High}$ (right panel) for each horizon.

[30] 74% on average in the post-World War II sample.

[31] The model tax multipliers fit the empirical tax multipliers only marginally better when I introduce capital and capital income taxes.



Notes: Impulse responses (in % of potential GDP) of real federal tax revenues and real GDP to a tax shock. Estimation from an asymmetric and state-dependent FAIR model with data covering 1947q1 to 2017q4. Identification using sign restrictions (Mountford and Uhlig, 2009). The shaded areas cover 90% over the posterior probability. Low, average, and high unemployment denotes de-trended unemployment rates of −1, 0, and +2 percent, respectively.

Fig. 8. Asymmetric and state-dependent impulse responses – FAIR with sign restrictions.

The model

Household. The household chooses consumption c_t, labor l_t, and nominal bonds B_t to maximize utility

$$\max \sum_{t=0}^{\infty} \beta_{0,t} \frac{c_t^{1-\sigma}}{1-\sigma} - \chi l_t^{\nu} \tag{10}$$

where σ is the risk aversion coefficient and $1/(\nu-1)$ is the Frisch elasticity of labor supply. $\beta_t \in (0,1)$ is a time-varying discount factor defined as $\beta_{t+1} = \beta_t e^{-(\rho+s_t)}$ with $\beta_0 = 1$ and $\rho + s_t$ the implied discount rate. The discount factor is subject to the shock s_t, the only source of business cycle fluctuations other than the tax shock. Total consumption is aggregated from differentiated goods as in Dixit and Stiglitz (1977). The household is subject to a standard No-Ponzi game condition, and the budget constraint

$$c_t + \frac{B_t}{P_t} = \frac{W_t}{P_t} l_t(1-\tau_t) + \frac{R_{t-1}B_{t-1}}{P_t} + t_t + \int_0^1 d(i)di, \tag{11}$$

where W_t is the nominal wage, τ_t is the income tax rate, R_{t-1} is the nominal interest rate, $d(i)$ is the profit of firm i, and t_t are lump-sum transfers. Solving the household problem yields a standard Euler equation and the expression for desired labor supply l_t^s

$$\chi\nu(l_t^s)^{\nu-1} = \frac{W_t}{P_t}(1-\tau) = w_t(1-\tau). \tag{12}$$

The desired labor supply depends on the real net-of-tax wage $(1-\tau)w_t$. I introduce DNWR as in Schmitt-Grohé and Uribe (2016) and assume

$$W_t \geq \gamma(u_t) W_{t-1}. \tag{13}$$

$\gamma(u_t)$ captures DNWR as a function of the unemployment rate. As in Schmitt-Grohé and Uribe (2012) and Barnichon et al. (2021), I relax the constraint when economic slack is high and assume the function is twice differentiable with $\gamma' \leq 0$ and $\gamma'' \geq 0$. Intuitively, firms are more likely to implement wage cuts, and workers are more likely to accept them when firms are facing distress (Akerlof et al., 1996).[32] The specification implies that the nominal wage W_t can not drop below the floor $\gamma(u_t)W_{t-1}$ and nests the extreme cases of no rigidity ($\gamma = 0$) and complete downward rigidity ($\gamma = 1$).[33] The unemployment rate is given by

[32] Akerlof et al.'s (1996) argument is based on a review of the ethnographical literature. For instance, Bewley (1995) surveys firms and reports that wage cuts are rare but more likely after a second year of losses. The interviews in Kahneman et al. (1986) show that most respondents view reductions in nominal wages as fair when the firm is losing money.

[33] We can rewrite (13) in real terms by dividing by the price level P_t on both sides to get $w_t\pi_t \geq \gamma(u_t)w_{t-1}$, where $\pi_t = \frac{P_t}{P_{t-1}}$ is the inflation rate.

$$u_t = \frac{l_t^s - l_t}{l_t^s}, \tag{14}$$

where l_t is employment and l_t^s is desired labor supply from Equation (12).

A large enough positive shock (or series of shocks) to the discount rate triggers a recession: the labor market clearing wage falls below the wage floor, and DNWR binds. In turn, the desired labor supply l_t^s exceeds labor used in production l_t, and the unemployment rate u_t increases. Similarly, negative discount rate shocks cause an expansion. They push the labor market, clearing wage up, thus reducing labor market slack. When the labor market clearing wage is above the wage floor, the labor market clears. Therefore, either the labor market clears ($l_t^s = l_t$) or downward rigidity binds ($W_t = \gamma(u_t)W_{t-1}$), giving rise to the condition

$$(l_t^s - l_t)(W_t - \gamma(u_t)W_{t-1}) = 0. \tag{15}$$

With DNWR, wages become less flexible when unemployment is high.[34] When the labor market clearing wage is below the wage floor, the realized wage responds only little to shifts in labor demand or supply.[35]

Firms and government. The firm side of the model is standard: the final good producer combines a continuum of differentiated intermediate goods. Intermediate goods firms use only labor in production and face price rigidities as in Calvo (1983).[36]

The government collects tax revenues $tr_t = w_t\tau_t l_t$ to finance lump sum transfers t_t, i.e. $w_t\tau_t l_t = t_t$. Monetary policy follows a standard interest rate rule $R_t = R\left(\frac{\pi_t}{\pi}\right)^{\phi_\pi}\left(1+\frac{u_t}{u^n}\right)^{-\phi_u}$, where ϕ_π and ϕ_u are the elasticities of the nominal interest rate to inflation and unemployment, respectively. R denotes the steady-state interest rate and π steady-state inflation. u^n is the natural unemployment rate, i.e., the unemployment rate absent nominal rigidities.[37]

5.1. Intuition

Tax rate changes shift the desired labor supply. Changes in desired labor supply affect the (realized and labor market clearing) real wage. The real wage determines the production level of employment (and hence unemployment) and production.

Asymmetry. After a tax cut, the labor market clearing wage decreases (see above). However, downward wage adjustments are constrained by DNWR. With the limited downward adjustment in the wage, employment, and production react only little to the tax cut. After a tax hike, on the other hand, the labor market clearing wage increases. Since the wage is upwardly flexible, the effects of a tax hike on employment and output are relatively strong.

Asymmetry and state dependence. In a recession, the wage exceeds the labor market clearing wage, and DNWR binds, resulting in less flexible wages. A tax change affects the desired labor supply and the labor market clearing wage. Since the wage is above the labor market clearing level, a tax change has relatively little effect on employment and production. Crucially, tax hikes still have larger effects than tax cuts in recessions. A tax cut further decreases the labor market clearing wage, which is already below the wage floor, and thus has little effect. A tax hike, however, lowers the desired labor supply and raises the labor market clearing wage. It, therefore, reduces the tightness of the DNWR constraint. It may even push the wage above the wage floor, at which point the effects of tax hikes are again large. In good times, the labor market clears, and wage is above the wage floor, resulting in a more flexible wage and larger effects of tax changes.

5.2. Quantitative example

To illustrate the degree of sign- and state-dependence the model can generate, I provide a quantitative example. Economic fluctuations are driven by business cycle shocks — shocks to the discount factor — following an AR(1) process

$$s_t = \lambda_s s_{t-1} + \epsilon_t^s \tag{16}$$

and tax shocks

$$ln\left(\frac{\tau_t}{\tau}\right) = \lambda_\tau ln\left(\frac{\tau_{t-1}}{\tau}\right) + \epsilon_t^\tau, \tag{17}$$

where $\epsilon_t^s \sim N(-\omega_s^2/2, \omega_s^2)$ and $\epsilon_t^\tau \sim N(0, \omega_\tau^2)$.

Parameters and Solution. I set $\tau = 0.29$, $\lambda_\tau = 0.9$, and $\omega_\tau = 0.01$, which correspond to the sample average, autocorrelation and standard deviation of the Barro and Redlick (2011) average marginal tax rate series. Following Fernández-Villaverde et al. (2010), I fix $\lambda_s = 0.14$. I calibrate the DNWR functional form following Barnichon et al. (2021).[38]

[34] See, for instance, Akerlof et al. (1996), Benigno and Ricci (2011), and Daly and Hobijn (2014).

[35] As described above, I relax DNWR when unemployment is high. This limits wage state dependence and allows me to match the empirical evidence in Daly and Hobijn (2014).

[36] See the online appendix for a detailed description of the firm side.

[37] Since variation in unemployment is only due to nominal rigidities in the model, u^n is constant.

[38] They propose $\gamma(u_t) = \gamma_0 + \frac{1}{\gamma_2}(\gamma_1 u_t)^{-\gamma_2}$ and set $\gamma_0 = 1$, $\gamma_1 = 33$, $\gamma_2 = 7$ to match the evidence of Daly and Hobijn (2014): (i) wage growth is positive at full employment (corresponding to a zero unemployment rate in the model), i.e., $\gamma(0) = 1$; (ii) annual wage deflation remains below 3% when unemployment is 1% above full employment, and (iii) annual wage deflation is below 4% when unemployment is 4% above full employment.

Table 2
Tax multipliers in the simulated model.

	Tax cut M^-	Tax hike M^+
Low unemployment M_{Low}	-2.07	-4.00
Average unemployment M_{Avg}	-1.91	-3.72
High unemployment M_{High}	-1.65	-3.18

Notes: The multiplier is the cumulative impulse response of output over the first 12 quarters divided by the cumulate impulse response of tax revenues over the first 12 quarters. Low (high) unemployment denotes a de-meaned unemployment rate of −1 percent (+2 percent).

The full employment unemployment rate, i.e., when there is no involuntary unemployment stemming from DNWR, in the model is zero (since it does not feature frictional unemployment).[39] I follow Barnichon et al. (2021) and treat a 4.5% unemployment rate as the minimum/full employment unemployment rate. I then set $\omega_s = 0.05$ such that the stochastic average unemployment rate equals 1.3%. This corresponds to a 5.8% unemployment rate in the data (minimum unemployment rate 4.5% + 1.3%), the sample average of the US unemployment rate.[40]

I use standard values for the remaining parameters: $\rho = 0.01$, $\sigma = 2$, and $\nu = 1.5$. I set steady state inflation to $\pi = 1$. I choose χ to achieve steady state employment $l = 1$, θ so that firms' markup is 15%, and $\omega = 0.75$, implying that firms reset prices one per year, on average. I set the parameters of the monetary policy rule to $\phi_\pi = 1.5$ and $\phi_u = 0.5$ following Galí (2011) and close to the estimates of Yellen (2004).[41]

Results. I obtain the cumulative multiplier for tax hikes and tax cuts at different unemployment rate levels. To that end, I compute impulse responses to (positive and negative) tax shocks for different realizations of the business cycle shock. I use Guerrieri and Iacoviello's (2015) OccBin toolkit to account for the occasionally binding DNWR constraint. As in the empirical exercise, I consider the unemployment rate to be *high* when it is 2ppt above and *low* when it is 1ppt below its historical average. Table 2 summarizes the model tax multipliers. We see that the model captures the two key empirical findings: (i) the tax hike multiplier is larger (in absolute value) than the tax cut multiplier, and (ii) the tax multiplier is weaker when slack is high.

The model generates a substantial degree of asymmetry and state dependence. For example, when the unemployment rate is at its average level, the difference between the tax hike and tax cut multipliers is $3.72\$ - 1.93\$ = 1.79\$$. Comparing these numbers to the results in Table 1, Panel A reveals that the model accounts for about two-thirds of the tax multiplier asymmetry in the data.[42] The difference between the low and high unemployment tax hike multipliers is $0.82\$$, about half of the empirical tax hike multiplier state dependence (Table 1 Panel B).

The model also predicts state dependence in the tax cut multiplier with a difference between low and high unemployment multipliers of $0.42\$$. While this is close to the empirical estimates, state dependence of the tax cut multiplier is statistically insignificant. This could indicate the model is missing a mechanism that offsets the pro-cyclicality of the tax cut multiplier from DNWR. For instance, with labor search frictions, tax cuts have larger effects in recessions (Ferraro and Fiori, 2021). Another possibility is that it is more difficult to detect statistically significant state dependence for the smaller tax cut multiplier due to a higher noise-to-signal ratio.[43]

In the online appendix, I explore the sensitivity of the results and consider (1) alternative calibrations of the monetary policy rule and (2) a constant degree of wage rigidity γ.[44] The model's key feature in generating asymmetry and state dependence is DNWR. Without DNWR ($\gamma = 0$), there is no variation in unemployment, and the tax multiplier is symmetrical in the sign of the tax shock and coincides with the tax hike multiplier at full employment in the complete model with DNWR.

5.3. Inspecting the mechanism

The model predicts that the multiplier is relatively large when the wage responds more strongly, i.e., after a tax hike and when unemployment is low. I inspect whether the mechanism is plausible by studying the effects of tax shocks on the average hourly

39 It is straightforward to introduce a non-zero full employment unemployment rate in the model by introducing labor search frictions. However, this would unnecessarily complicate the model without adding much additional insight.

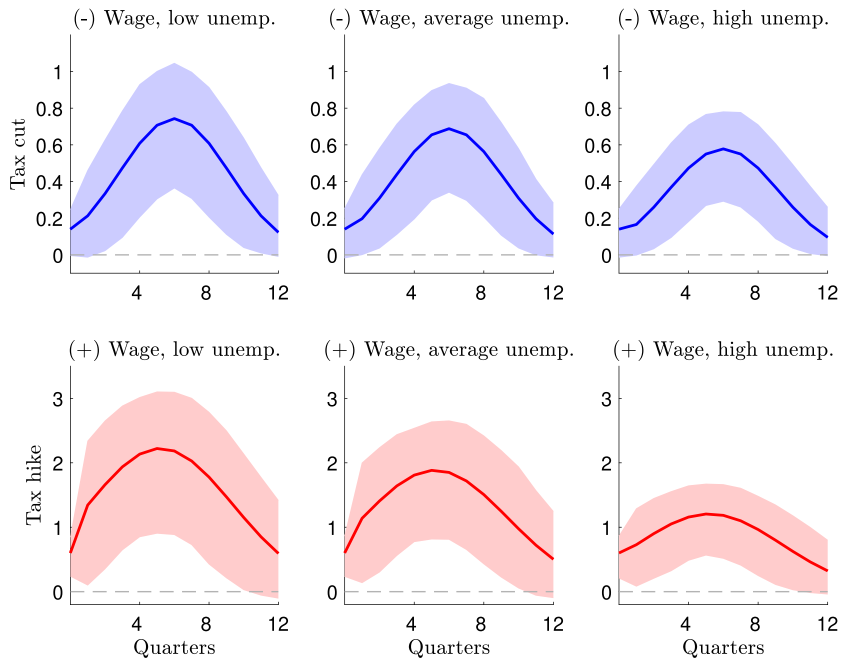
40 Without any shocks, the economy would operate at the minimum unemployment rate.

41 Yellen (2004) regresses the annualized Fed funds rate on the unemployment gap and annualized inflation and finds coefficients of 1.7 on both. This implies $\phi_\pi = 1.7$ and $\phi_u = 1.7/4 = 0.43$ at quarterly frequency.

42 The difference between tax hike and tax cut multipliers is $3.74\$ - 1.36\$ = 2.38\$$ using the narrative approach and $4.01\$ - 1.22\$ = 2.79\$$ using sign restrictions.

43 The smaller the effect of tax changes on output, the more difficult it is to find statistically significant results. The extent of state dependence in the model may be difficult to detect because the tax cut multiplier is relatively small and the effects of other shocks on output dominate, i.e., there is a high noise-to-signal ratio.

44 (1) The model generates substantial asymmetry and state dependence for alternative plausible calibrations of the policy rule. However, asymmetry and state dependence weaken the larger the weights on inflation and unemployment. For very large values of ϕ_π or ϕ_u, asymmetry disappears because DNWR never binds, and there is no variation in unemployment. (2) With a fixed γ, downward rigidity does not ease when unemployment is high, and the model generates slightly more state dependence.



Notes: Impulse responses of real average hourly compensation to a tax shock (in %). Estimation from an asymmetric and state-dependent FAIR model with data covering 1947q1 to 2017q4. Identification using Romer and Romer's (2010) narrative measure of exogenous changes in federal tax liabilities as an instrumental variable. The shaded areas cover 90% over the posterior probability. Low, average, and high unemployment denotes de-trended unemployment rates of -1, 0, and $+2$ percent, respectively.

Fig. 9. Asymmetric and state dependent wage responses – FAIR with external instrument.

real wage. To do so, I add log average hourly compensation[45] to the vector of endogenous variables and re-estimate the FAIR model.

I first consider the narrative approach. Fig. 9 shows the responses (in percent) to tax cuts and tax hikes for three different levels of unemployment. Table 3 reports that the peak response to a tax hike is $max(\psi^+) = 1.88\%$, and to a tax cut $max(\psi^-) = 0.69\%$. The evidence in favor of asymmetry is strong as the posterior probability that the peak response to a tax hike is stronger than to a tax cut, i.e., $max(\psi^+) > max(\psi^-)$ is above 0.95. Turning to state dependence, the peak response to a tax hike is $max(\psi^+_{Low}) = 2.22\%$ when unemployment is low and $max(\psi^+_{High}) = 1.21\%$ when unemployment is high. State dependence of the wage response to a tax hike is significant. The posterior probability that $max(\psi^+_{Low}) > max(\psi^+_{High})$ is above 0.95. The peak response to a tax cut is $max(\psi^-_{Low}) = 0.74\%$ when slack is low and $max(\psi^-_{High}) = 0.58\%$. Similar to the tax multiplier, the wage response to a tax cut appears to get stronger when unemployment is low, but state dependence is not statistically significant (the posterior probability that $max(\psi^+_{Low}) > max(\psi^+_{High})$ is 0.75).

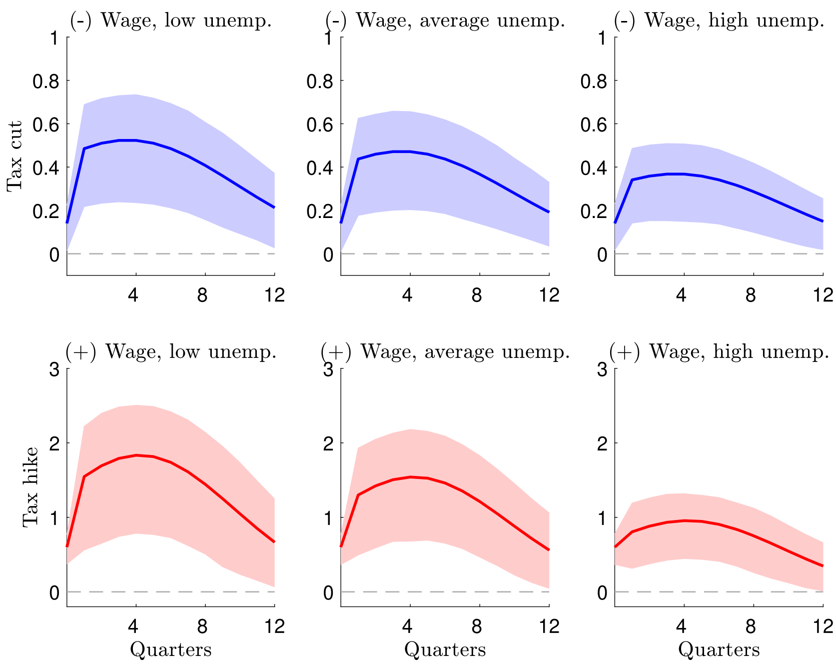
Fig. 10 shows the results using sign restrictions. The peak response to a tax hike is $max(\psi^+) = 1.54\%$, and to a tax cut $max(\psi^-) = 0.47\%$ at an average unemployment level. The evidence in favor of asymmetry is again strong as the posterior probability that the peak response to a tax hike is stronger is above 0.95. The peak response to a tax hike is $max(\psi^+_{Low}) = 1.83\%$ when unemployment is low and $max(\psi^+_{High}) = 0.96\%$ when unemployment is high. State dependence is borderline statistically significant as $P\left(max(\psi^+_{Low}) > max(\psi^+_{High})\right) = 0.90$. The peak response to a tax cut is $max(\psi^-_{Low}) = 0.52\%$ when slack is low and $max(\psi^-_{High}) = 0.37\%$ when slack is high. As before, the wage response to a tax cut appears to be larger when unemployment is low, but state dependence is not statistically significant (the posterior probability that $max(\psi^+_{Low}) > max(\psi^+_{High})$ is 0.71).

These findings are consistent with the model predictions and suggest that asymmetric and state-dependent wage responses are a plausible channel to explain the tax multiplier results. Nevertheless, other mechanisms are possible and likely to contribute to tax multiplier asymmetry and state dependence. Potential candidates are, for instance, search frictions in the goods market (Ghassibe and Zanetti, 2022), labor search frictions (Michaillat, 2014), or financial frictions.

6. Conclusion

This paper shows that the US tax multiplier depends on the sign of the tax change. Using the two leading identification strategies, the tax hike multiplier is about three times larger than the tax cut multiplier. In addition, the tax hike multiplier is substantially

[45] I allow for a quartic deterministic trend in log wages. I use hourly compensation in the non-farm business sector from the Bureau of Labor Statistics, FRED series PRS85006152.



Notes: Impulse responses of real average hourly compensation to a tax shock (in %). Estimation from an asymmetric and state-dependent FAIR model with data covering 1947q1 to 2017q4. Identification using sign restrictions (Mountford and Uhlig, 2009). The shaded areas cover 90% over the posterior probability. Low, average, and high unemployment denotes de-trended unemployment rates of −1, 0, and +2 percent, respectively.

Fig. 10. Asymmetric and state-dependent wage responses – FAIR with sign restrictions.

Table 3
Peak wage responses.

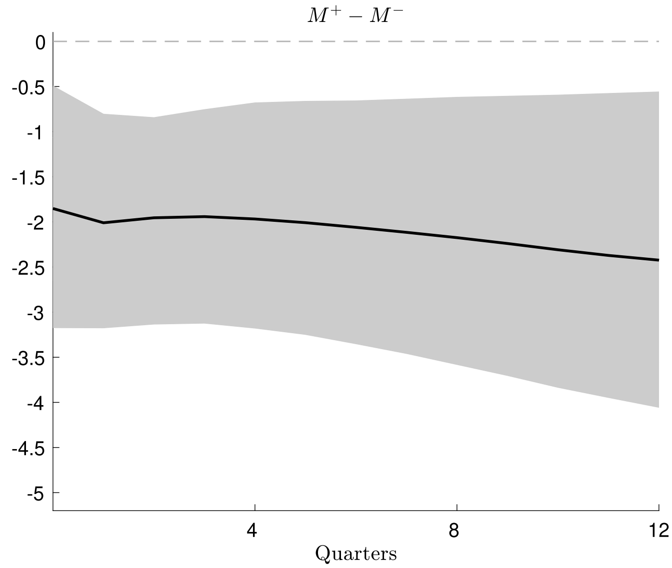
	Linear $max(\psi_w)$	Tax cut $max(\psi_w^+)$	Tax hike $max(\psi_w^-)$	Difference $max(\psi_w^+) > max(\psi_w^-)$
	A. Asymmetric wage response			
Narrative approach	1.17	0.69	1.88	$P > 0.95^{**}$
90% posterior probability	(0.63, 1.76)	(0.34, 0.94)	(0.82, 2.64)	
Sign restrictions	1.00	0.47	1.54	$P > 0.95^{**}$
90% posterior probability	(0.44, 1.58)	(0.20, 0.69)	(0.66, 2.18)	
	B. Asymmetric and slack-dependent wage response			
Narrative approach				
Low unemployment $max(\psi_{Low})$		0.74	2.22	$P > 0.95^{**}$
90% posterior probability		(0.36, 1.05)	(0.91, 3.10)	
High unemployment $max(\psi_{High})$		0.58	1.21	$P > 0.90^{*}$
90% posterior probability		(0.29, 0.78)	(0.57, 1.67)	
P $(max(\psi_{Low}) < max(\psi_{High}))$		$P = 0.75$	$P > 0.95^{**}$	
Sign restrictions				
Low unemployment $max(\psi_{Low})$		0.52	1.83	$P > 0.95^{**}$
90% posterior probability		(0.24, 0.73)	(0.79, 2.51)	
High unemployment $max(\psi_{High})$		0.37	0.96	$P > 0.90^{*}$
90% posterior probability		(0.15, 0.51)	(0.45, 1.32)	
P $(max(\psi_{Low}) < max(\psi_{High}))$		$P = 0.71$	$P = 0.90^{*}$	

Notes: The peak response is the maximum increase in the average hourly wage following a tax shock (in %). Panel A: Estimation from a sign-dependent (asymmetric) FAIR model. Panel B: Estimation from an asymmetric and state-dependent FAIR model. Estimation using data from 1947q1 to 2017q4. Narrative approach: identification using Romer and Romer's (2010) narrative measure of exogenous changes in federal tax liabilities as an instrumental variable. Sign restrictions: identification using sign restrictions on impulse responses (Mountford and Uhlig, 2009). Low (high) unemployment denotes a de-trended unemployment rate of −1 percent (+2 percent).

larger in recessions. The tax cut multiplier varies less (and statistically insignificantly) over the business cycle. While still sizeable, the gap between the tax hike and tax cut multiplier thus narrows during recessions and widens during expansions.

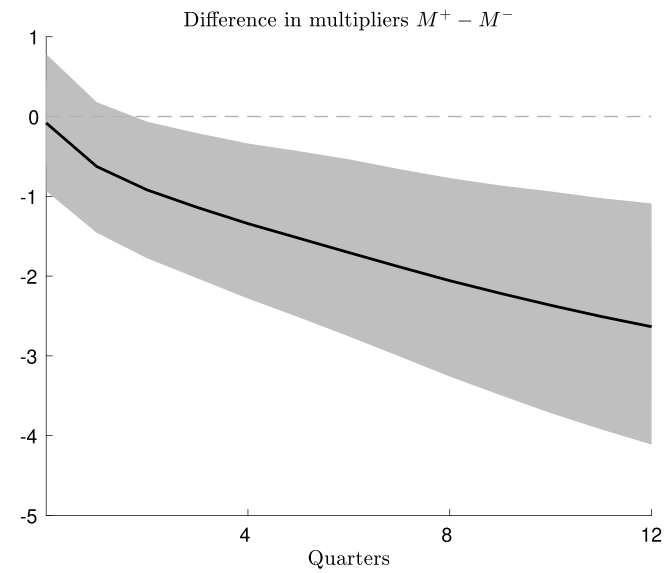
The results have important implications for fiscal policy: tax hikes effectively cool a booming economy, while tax cuts have limited power to stimulate during a recession. An interesting next step is to study separately the sign- and state-dependent effects of different components of tax policy (e.g., personal income, corporate income, and payroll tax changes), possibly by building on the narrative series in Mertens and Ravn (2013).

Appendix A



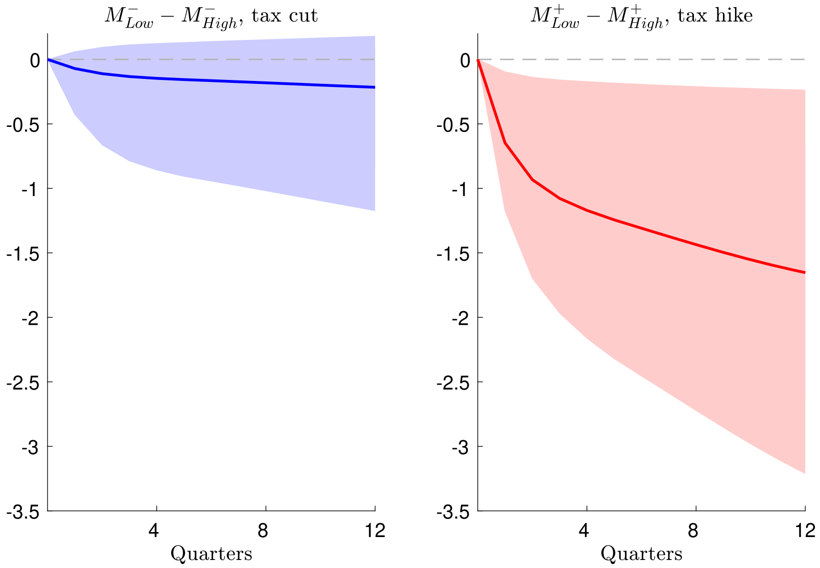
Notes: Difference between tax multiplier associated with positive tax shocks (tax hike, M^+) and tax multiplier associated with negative tax shocks (tax cut, M^-). Estimation from a sign-dependent (asymmetric) FAIR model with data covering 1947q1 to 2017q4. Identification using Romer and Romer's (2010) narrative measure of exogenous changes in federal tax liabilities as an instrumental variable. The shaded areas cover 90% over the posterior probability.

Fig. A.1. Difference between tax hike and tax cut multiplier – FAIR with external instrument.



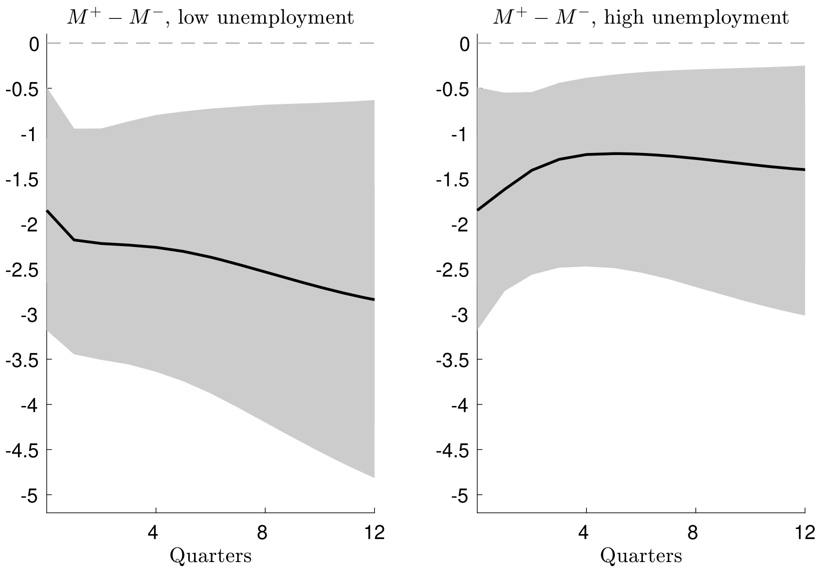
Notes: Difference between tax multiplier associated with positive tax shocks (tax hike, M^+) and tax multiplier associated with negative tax shocks (tax cut, M^-). Estimation from a sign-dependent (asymmetric) FAIR model with data covering 1947q1 to 2017q4. Identification using sign restrictions (Mountford and Uhlig, 2009). The shaded areas cover 90% over the posterior probability.

Fig. A.2. Difference between tax hike and tax cut multiplier – FAIR with sign restrictions.



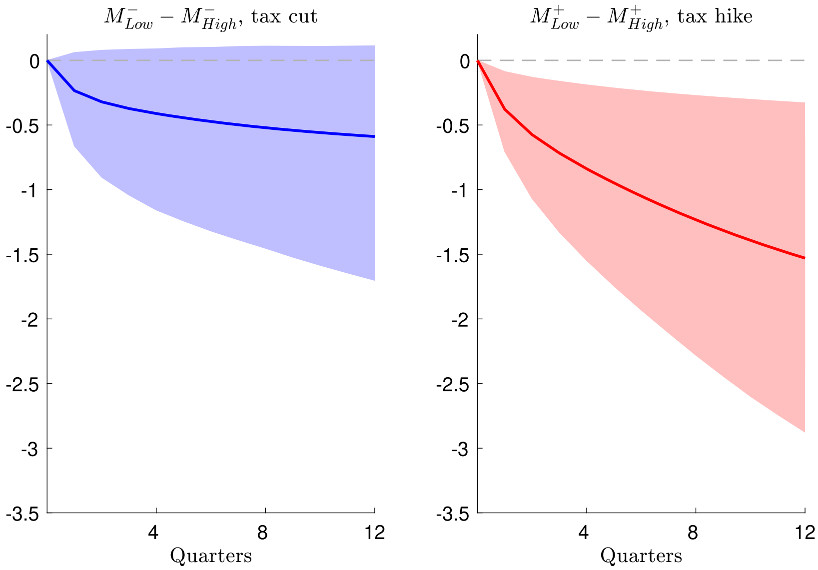
Notes: The left panel shows the difference between the low and high slack tax cut multiplier. The right panel shows the difference between the low and high slack tax hike multiplier. Estimation from an asymmetric and state-dependent FAIR model with data covering 1947q1 to 2017q4. Identification using Romer and Romer's (2010) narrative measure of exogenous changes in federal tax liabilities as an instrumental variable. The shaded areas cover 90% over the posterior probability. Low (high) slack denotes a de-trended unemployment rate of −1 percent (+2 percent).

Fig. A.3. Difference between low and high slack multiplier – FAIR with external instrument.



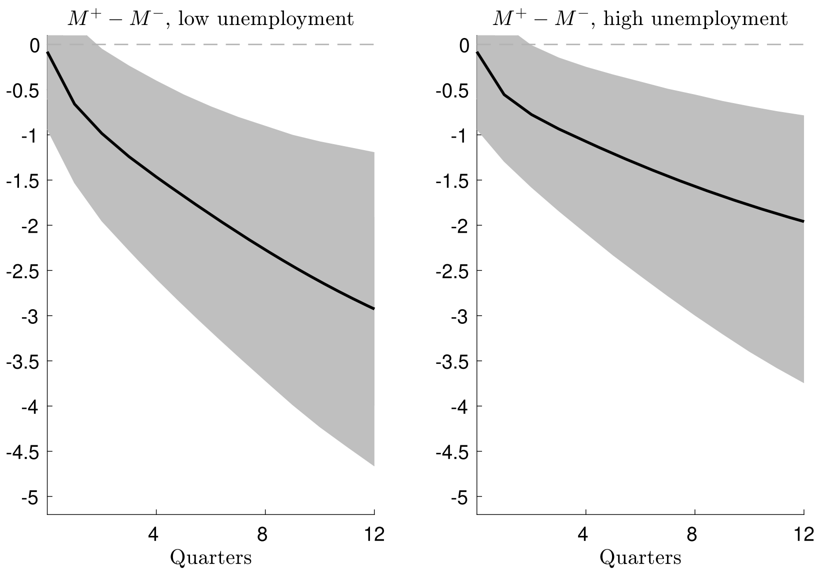
Notes: Difference between tax multiplier associated with positive tax shocks (tax hike, M^+) and tax multiplier associated with negative tax shocks (tax cut, M^-) when unemployment is low (left panel) or when unemployment is high (right panel). Low (high) unemployment denotes a de-trended unemployment rate of −1 percent (+2 percent). Estimation from an asymmetric and state-dependent FAIR model with data covering 1947q1 to 2017q4. Identification using Romer and Romer's (2010) narrative measure of exogenous changes in federal tax liabilities as an instrumental variable. The shaded areas cover 90% over the posterior probability.

Fig. A.4. Difference between tax hike and tax cut multiplier and economic slack – FAIR with external instrument.



Notes: The left panel shows the difference between the low and high slack tax cut multiplier. The right panel shows the difference between the low and high slack tax hike multiplier. Estimation from an asymmetric and state-dependent FAIR model with data covering 1947q1 to 2017q4. Identification using sign restrictions (Mountford and Uhlig, 2009). The shaded areas cover 90% over the posterior probability. Low (high) slack denotes a de-trended unemployment rate of −1 percent (+2 percent).

Fig. A.5. Difference between low and high slack multiplier – FAIR with sign restrictions.



Notes: Difference between tax multiplier associated with positive tax shocks (tax hike, M^+) and tax multiplier associated with negative tax shocks (tax cut, M^-) when unemployment is low (left panel) or when unemployment is high (right panel). Low (high) unemployment denotes a de-trended unemployment rate of −1 percent (+2 percent). Estimation from an asymmetric and state-dependent FAIR model with data covering 1947q1 to 2017q4. Identification using sign restrictions (Mountford and Uhlig, 2009). The shaded areas cover 90% over the posterior probability.

Fig. A.6. Difference between tax hike and tax cut multiplier and economic slack – FAIR with sign restrictions.

Appendix B. Supplementary material

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jedc.2023.104785.

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