Can tax cuts restore economic growth in bad times?*

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JOB MARKET PAPER

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Abstract

I present empirical evidence that the effects of U.S. tax changes on output depend on the level of economic slack. Tax cuts have large effects in good times, but only small and statistically insignificant effects in bad times. The finding holds across different identification schemes, many alternative specifications, and when I consider shocks to the two largest tax categories—personal and corporate income taxes—separately. To explain the finding, I develop a search model of unemployment, in which the effect of a tax cut is small when unemployment is high. A tax cut raises the utility gain from work and thus stimulates jobseekers’ job-search effort. The higher search effort reduces search frictions, which makes it less costly for firms to hire new workers, and therefore raises employment and production. When labor demand is depressed, however, the number of jobseekers per vacancy is large and search frictions do not matter much. As a result, a tax cut that raises search effort has little effect on employment and output.

JEL Codes: E12, E24, E32, E62, H24, H30

Keywords: Fiscal policy, tax changes, business cycle, matching frictions, local projections

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*I thank Regis Barnichon for continuous guidance and support throughout this project. I would also like to thank Isaac Bale, Andrea Caggese, Giacomo Caracciolo, Davide Deboitoli, Luca Fornaro, Jordi Gali, Jared Gars, Christoph Hedtrich, Edouard Schaal, Donghai Zhang and seminar participants at CREI-Universitat Pompeu Fabra for insightful comments. I am extremely grateful to Dijana Zejcirovic for her invaluable and constant support and feedback during the writing of this paper. All remaining errors are my own.

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1 Introduction

The effects of tax changes on economic activity are subject to constant policy analysis and debate. In particular in times of low economic growth and high unemployment, politicians often argue that tax cuts can revive the economy. In the U.S., bringing employment and output back to potential is commonly stated explicitly as a motivating factor behind a tax cut. But is this a viable strategy? Can tax cuts restore economic growth in bad times? While recent empirical work suggests that tax changes have large effects on output on average, there is no evidence on how these effects vary with the state of the economy.

In this paper, I present empirical evidence that the effects of U.S. tax changes on output depend on the level of economic slack. In good times, tax shocks have large effects on output—much larger than estimates from a linear model suggest. In bad times, on the other hand, tax shocks have small and statistically insignificant effects on output. The finding holds for two leading identification schemes, for a variety of alternative specifications, and when I consider tax shocks to the two largest tax categories—personal and corporate income taxes—separately. In addition, tax shocks have large effects on employment, consumption, and investment only in good times. The effects of a tax shock on the real wage are small, statistically insignificant and do not depend on economic slack.

To explain the results, I develop a simple search model of unemployment, in which the income tax multiplier is small when unemployment is high. I focus on an income tax because it is by far the largest tax category. The effect of a tax change depends on economic slack, because of (i) the presence of search frictions in the labor market and (ii) job rationing, i.e. the labor market does not clear in the absence of search frictions. An income tax cut raises the utility gain from work and thus stimulates jobseekers’ job-search effort. The higher search effort reduces search frictions, which makes it less costly for firms to hire additional workers, and hence raises employment and production. When labor demand is depressed and unemployment is high, however, the number of jobseekers per vacancy is large and recruiting is easy and inexpensive, so search frictions do not matter much. As a result, a tax cut that raises search effort has only small effects on employment and output. The same mechanism leads to a large effect on employment and output when unemployment is low and the matching process is congested by vacancies.

In Section 2, I present my baseline empirical framework. To identify tax shocks, I build on Romer and Romer’s (2010) narrative measure of exogenous tax changes constructed from historical sources. My key identifying assumption is that the narrative measure correlates with the unobserved tax shock, but is uncorrelated with other shocks. Thus, I use the narrative measure as an external instrument for the tax shock. I prefer the narrative approach over a purely statistical one because it addresses more convincingly the possibilities of forward-
looking policy or correlations with non-cyclical, non-policy influences on tax revenues and other determinants of output. I use an instrumental variable (IV) approach because the identification assumption is weaker than assuming the narrative account measures the true tax shock without error. To estimate impulse responses, I use Jordà’s (2005) local projections method (LP), and I use the lagged unemployment rate as a measure of economic slack. I choose the unemployment rate as it is a widely accepted measure of underutilized resources. The LP method is more robust to arbitrary forms of model misspecification than the more conventional VAR. In addition, with the LP method, one does not have to take a stand on how the shock affects the state of economy.3

In Section 3, I present the main finding that tax shocks have large effects on output in good times, but only small and statistically insignificant effects in bad times. In fact, estimates from a linear model are approximately a weighted average of large effects when economic slack is low, and small effects when economic slack is high. I show that the same finding emerges with the Blanchard and Perotti (2002) identification strategy that imposes short-run restrictions in a structural VAR. Digging deeper, I examine whether one of the two largest tax categories is driving the result. I consider personal income taxes, which account for on average 74 percent of total federal tax revenues, and corporate income taxes, which account for on average 16 percent. Specifically, I use the decomposition of the narrative measure into the two subcategories by Mertens and Ravn (2013). However, the number of exogenous tax changes per category is small, which generates an efficiency problem when using a method as flexible as LP. To address the issue, I develop a new Bayesian method that allows to flexibly combine the advantages of VARs and LPs. My method allows to maintain much of the efficiency of the VAR while relaxing its strong parametric restrictions. The main idea is to use LPs with informative priors centered around the iterated VAR impulse response function. Applying my new method, I find that both tax categories have large effects in good times, and small and insignificant effects in bad times.

In Section 4, I develop a simple search-and-matching model to provide a structural interpretation for the result. I perform a comparative steady-states analysis to highlight the key economic forces at work. I derive an analytical expression for the income tax multiplier and represent the equilibrium diagrammatically. The steady-state equilibrium is the intersection of a convex and upward-sloping quasi-labor supply and a downward-sloping labor demand in an (employment, labor market tightness) plane. The quasi-labor supply is the employment rate when labor market flows are balanced. The properties of the curves arise from a standard matching function and a production function with diminishing marginal returns to labor. An income tax cut raises the utility gain from work and thereby stimulates jobseekers’ job-search effort. In the diagram, the quasi-labor supply shifts outwards. The higher search effort reduces tightness, which makes it less costly for firms to hire new workers, and hence raises employment. I compare a steady-state to another steady-state with lower labor demand and thus higher unemployment. The effect of a tax cut on employment and output is determined by the amplitude of the reduction in tightness. When labor demand is lower, a tax cut has a smaller effect on tightness because the quasi-labor supply is convex. Intuitively, in recessions, jobs are lacking, labor market tightness is low, and search frictions do not matter much. Thus, a tax cut that

3In this context, the LP method, therefore, dominates a VAR which requires additional assumptions on the path of the state variable.
raises search effort has only little influence on tightness and employment.

To improve realism, I embed the search-and-matching model into a New Keynesian model. Unemployment fluctuates because the economy is subject to technology shocks and real wage rigidities. I compare the effect of a technology shock when it is accompanied by a tax change and when it is not. The peak effect of an income tax cut on output falls from 0.41% to 0.12% when the unemployment rate increases from 5 percent to 8 percent. I conclude the section by discussing some of the model’s shortcomings, and the ability of competing explanations to rationalize the patterns I find in the data.

The findings of the paper question whether estimates of the average effects of tax shocks from a linear model can provide meaningful guidance for fiscal policy. My paper is complementary to empirical work that studies whether the government spending multiplier is larger in bad times. Interestingly, these papers find that the government spending multiplier is either larger in bad times (see for example Auerbach and Gorodnichenko 2012a; 2012b; Fazzari et al., 2015), or does not depend on economic slack (Ramey and Zubairy, 2016). I recover the opposite result for the effects of tax shocks. My paper builds on and complements the theoretical work of Michaillat (2014). In his model, a public employment multiplier increases when the unemployment rate is high. I extend the model of Michaillat (2014) to allow for endogenous job-search effort and show that the model can also rationalize the finding that tax shocks have larger effects when unemployment is low. Section 5 concludes with some thoughts for future research.

2 Empirical Framework

In this section, I first lay out my identification strategy. Then, I present my econometric specification and my baseline measure of economic slack.

2.1 Identification

My identification strategy is based on Romer and Romer’s (2010, henceforth RR) narrative measure of exogenous U.S. tax changes. RR use historical sources to record 110 U.S. tax code changes between 1947Q1 and 2007Q4 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 deficits), or, to raise long-run growth. RR 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. Following this definition, 51 tax changes are exogenous. Some are legislated in the same quarter, such that exogenous tax changes occur in 45 quarters. I follow RR and divide tax liability changes by (lagged) nominal GDP. Hence tax changes are expressed in percentage of GDP. Figure 1 plots the narrative measure. We see that exogenous tax changes are fairly equally distributed over the sample. The standard deviation is 0.24, and the standard deviation of non-zero observations is 0.55.

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4 Such as presidential speeches, the Economic Report of the President, and reports of Congressional committees.

5 I follow Mertens and Ravn (2014) and remove the mean from non-zero observations. The mean is approximately zero.
My key identification strategy is that the narrative measure correlates with the latent tax shock but is uncorrelated with other structural shocks. Hence, I use the narrative measure as an external instrument for the latent tax shock. This identification assumption is weaker than assuming that the narrative measure is equal to the unobserved tax shock. In practice, the construction of the narrative measure from historical sources likely introduces measurement error. Historical records sometimes contradict each other which makes judgment calls impossible to avoid. My strategy takes this into account. I only require that the narrative measure correlates with the unobserved tax shock, but the correlation does not need to be perfect.

The narrative approach has two advantages. First, it addresses the possibilities of forward-looking policy or correlations between non-cyclical, non-policy influences on revenues and other determinants. Purely statistical approaches, on the other hand, typically assume that once one corrects for the impact of output on tax revenues and controls for government spending, changes in revenues are uncorrelated with other determinants of output (see Perotti, 1999 and Blanchard and Perotti, 2002). Second, it allows me to sidestep the VAR and use Jordà’s (2005) local projection (LP) method.

2.2 Econometric Method

I estimate impulse responses to a tax shock with the LP method. The LP method has two advantages over the more conventional VAR. First, it is more robust to arbitrary forms of model misspecification. This is important in the context of tax shocks as the literature documents that small specification changes, such as number of lags assumed in the VAR or an additional control variable, lead to drastically different results. Second, the LP method can be adapted to allow for state-dependent impulse responses without taking a stand on how the economy transitions from state to state. In a state-dependent VAR, one needs to impose additional assumptions on how the shock affects the state variable. A common assumption is that the shock does not alter the state over the impulse response horizon. This seems implausible in the context of tax shocks as empirical evidence points to large effects.

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6The approach is related to Mertens and Ravn (2014) who use the narrative measure to identify parameters in a structural VAR.


8Leeper et al. (2011) point out that fiscal foresight could cause a misalignment between the agents’ and the econometrician’s information set, thus making it impossible to extract meaningful shocks to taxes from statistical innovations in a VAR.

9For a detailed discussion, see Perotti (2012).

10Appendix A clarifies this point analytically.

11See for example Auerbach and Gorodnichenko (2012b) and Ramey and Zubairy (2016).
2.3 Linear Specification

I combine the LP method with the RR narrative measure as an instrumental variable (IV) for the latent tax shock (LP-IV).\textsuperscript{12,13} To establish a benchmark, I first estimate a linear model:

\[
x_{t+h} = \alpha_h + \beta_h ATR_t + \gamma'_h z_t + \delta'_h D_t + u_{t+h}.
\] \hfill (1)

$ATR_t$ is the average tax rate, defined as federal tax revenues minus transfers divided by lagged nominal GDP. $x_t$ is the dependent variable of interest. I estimate impulse responses for log real GDP ($Y_t$), log real federal government spending ($G_t$) and $ATR_t$, hence $x_t = \{Y_t, G_t, ATR_t\}$. $z_t$ is a vector of control variables. $D_t$ are deterministic terms. I use quarterly data from 1947Q1 to 2007Q4.\textsuperscript{15} The impulse response of variable $x$ at horizon $h \in \{0, H\}$ to a tax shock is given by $\theta_h = \beta_h \sigma_T$, where $\sigma_T$ is the scale of the tax shock. Since $ATR_t$ is endogenous, OLS-estimation of (1) is invalid. Instead, with a suitable instrument, (1) can be estimated by LP-IV. I propose the RR narrative measure $RR_t$ as an IV for the latent tax shock $\epsilon^*_t$. $RR_t$ can be used to estimate the causal effects of tax shocks if it satisfies the conditions for instrument validity.

I define $x^\perp_t = x_t - \text{Proj}(y_t | z_t)$ for some variable $y_t$ and controls $z_t$. That is $y^\perp_t$ describes the variation in $y_t$ orthogonal to the controls $z_t$. Moreover, I define the vector of structural shocks $\epsilon_t = [\epsilon^*_t \epsilon^\perp_t]'$. Hence, $\epsilon_t$ contains the tax shock and all other structural shocks denoted by $\epsilon^*_t$. In the notation of Stock and Watson (2017), the conditions for instrument validity are:

\[
E \left( \epsilon^\perp_t RR^\perp_t \right) = 0 \quad \text{(Contemporaneous Exogeneity)}
\]
\[
E \left( \epsilon^\perp_t RR^\perp_j \right) = 0 \quad \text{for } j \neq 0 \quad \text{(Lead/Lag Exogeneity)}
\]
\[
E \left( \epsilon^*_t RR^\perp_t \right) = \mu \neq 0. \quad \text{(Relevance)}
\]

The first condition states that $RR_t$ must be uncorrelated with other shocks. The second condition states that $RR_t$ must be uncorrelated with past and future structural shocks. The third condition states that $RR_t$ must be correlated with the latent structural tax shock.

**Exogeneity.**—The first condition is likely satisfied. RR specifically employ the narrative approach to avoid that tax changes in $RR_t$ are driven by current or short-term economic conditions. Moreover, legislative lags make it unlikely that other contemporaneous factors affect $RR_t$. RR, Mertens and Ravn (2012) and Favero and Giavazzi (2012) provide evidence that the second requirement is likely satisfied. They all fail to reject the hypothesis that $RR_t$ is unpredictable by past observations of macroeconomic aggregates. In addition, I can not reject the null of no serial correlation in a regression of $RR_t$ on its own lags.

**Relevance.**—The third condition can be tested empirically through the first stage of (1). I report the first stage regression results in the beginning of the next section.

**Controls and deterministic terms.**—Because the exogeneity requirements are likely satisfied,
I can estimate $\beta_h$ consistently by LP-IV without controls. However, controls may increase estimator efficiency by reducing the variance of the error term. To that end, I add four lags of $Y_t$, $G_t$ and $ATR_t$ to the set of controls. $D_t$ includes a quadratic trend and, following Blanchard and Perotti (2002), a dummy for 1975Q2. With this choice of controls, the specification closely resembles the setup in a standard fiscal VAR.\footnote{See for example Blanchard and Perotti (2002), Auerbach and Gorodnichenko (2012b), and Mertens and Ravn (2014). Standard fiscal VARs use log real federal tax revenues instead of the average tax rate. I prefer the average tax rate because it corresponds more closely to a policy instrument. Political debates usually evolve around changes in tax rates and less about changes in tax revenues. However, none of the results is sensitive to using log real federal tax revenues instead.} I later investigate whether the results are robust to expanding the set of controls.

\textit{Shock scale.}—Since the tax shock is unobserved, $\sigma_\tau$ is indeterminate. The scale ambiguity is resolved by adopting, without loss of generality, a normalization for the scale of $\epsilon_\tau^t$. My normalization rests on the first stage of (1):

$$ATR_t = a + \sigma_\tau RR_t + c'z_t + d'D_t + e_t,$$

I define the point estimate of the coefficient on $RR_t$ as the scale of the tax shock. The normalization is convenient because the point estimates of $\theta_h$ are now directly comparable to impulse response estimates from studies that treat $RR_t$ as the tax shock.\footnote{For example RR, Mertens and Ravn (2011; 2012), Favero and Giavazzi (2012), Perotti (2012).}

2.4 State-Dependent Specification

I now extend the model to allow for state-dependent impulse responses to a tax shock:

$$x_{t+h} = I_{t-1} \left[ \alpha_h^B + \beta_h^B ATR_t + \gamma_h^B z_t \right] + (1 - I_{t-1}) \left[ \alpha_h^G + \beta_h^G ATR_t + \gamma_h^G z_t \right] + \delta_h'D_t + u_{t+h}. \tag{3}$$

$I_{t-1}$ is the state variable. The superscript $B$ denotes the bad state and $G$ denotes the good state of the economy. $I_{t-1} \times RR_t$ serves as an instrument for $I_{t-1} \times \epsilon_\tau^t$, and $(1 - I_{t-1}) \times RR_t$ as an instrument for $(1 - I_{t-1}) \times \epsilon_\tau^t$. The impulse response of variable $x$ at horizon $h \in \{0, H\}$ to a tax shock is given by $\theta_h^B = \beta_h^B \sigma_\tau$ if the shock hits in bad times, and by $\theta_h^G = \beta_h^G \sigma_\tau$ if the shock hits in good times.

I estimate (1) and (3) by two-stage least squares (TSLS). To construct confidence bands, I follow Ramey and Zubairy (2016) and use the Driscoll and Kraay (1998) method to adjust standard errors for the possibility of correlation in the residuals across dates $t$ and impulse response horizons $h$. This is akin to estimating the parameters equation by equation and then averaging the moment conditions across horizons $h$ when calculating Newey-West (1987) standard errors. Following Jordà (2005), I set the maximum autocorrelation lag to $h + 1$.

2.5 The State Variable

There are many variables that may describe the state of the economy. Some measure economic slack, such as the unemployment rate, capacity utilization or the output gap. Others capture the state of the business cycle, such as NBER recession dates or output growth. In addition,
one has to decide between a discrete thresholds that separates the good from the bad state and a continuous state variable. The literature has used a variety of different combinations.\footnote{For example, Owyang et al. (2013) and Ramey and Zubairy (2016) use the lagged unemployment rate with a discrete threshold of 6.5%. Fazzari et al. (2015) use lagged capacity utilization with a discrete threshold of 85%. Barro and Redlick (2011) use the standardized lagged unemployment rate. Auerbach and Gorodnichenko (2012b) and Tenreyro and Thwaites (2016) use a smooth transition function of the moving average of output growth.}

I interpret bad times as times of high economic slack. Following Owyang et al. (2013) and Ramey and Zubairy (2016), I define the economy to be in a high slack state if the lagged unemployment rate is above 6.5%. Thus, $I_{t-1} = 1$ if $U_{t-1} > 6.5\%$. I use the unemployment rate because it is a widely accepted measure of underutilized resources. The discrete threshold allows for an easy interpretation of the results. I later investigate the robustness of the results to alternative choices. Figure 2 plots the unemployment rate together with the RR narrative measure. We see that there is no systematic relationship between the two series. The economy is in the bad state in 66 quarters and in the good state in 178 quarters. 19 tax changes occur in bad times (standard error 0.6) of which 13 are tax increases and 6 tax cuts. 26 tax changes occur in good times (standard error 0.5) of which 12 are tax increases and 14 tax cuts.

### 3 Empirical Results

In this section, I first present the baseline results. I then investigate the robustness of the results to using an alternative identification strategy. I continue with a sensitivity analysis. Next, I study impulse responses of other important macroeconomic aggregates. Lastly, I distinguish between the effects of personal and corporate income tax shocks.

#### 3.1 First Stage

Instrument relevance can be evaluated through the first stage of (1) for the linear model, and the first stage of (3) for the state-dependent model.\footnote{Since errors may be serially correlated in the first stage, I report F-statistics based on Newey-West (1987) corrected standard errors with automatic lag selection.} The F-statistic for excluding $RR_t$ in the first stage of (1) is 11.4.\footnote{Ramey (2016) runs a similar regression and reports a first stage F-statistic of 3.2. However, she only uses a subset of the RR tax changes that removes 18 (out of 45) non-zero observations.} The F-statistic for excluding $I_{t-1} \times RR_t$ in a regression of $I_{t-1} \times ATR_t$ on all variables on the right side of (3) is 15.8. The F-statistic for excluding $(1 - I_{t-1}) \times RR_t$ in a regression of $(1 - I_{t-1}) \times ATR_t$ on all variables on the right side of (3) is 12.6. Thus, the F-statistic is 15.8 in bad times and 12.8 in good times. To further explore instrument relevance, I consider two tax measures as alternatives for the average tax rate. First, I use the average marginal tax rate (AMTR). This is the income-weighted average of the individual marginal tax rates faced by agents included in the aggregate. Barro and Redlick (2011) construct the AMTR at annual frequency. When I estimate the first stage of (3) using annual data and the AMTR, the F-statistic is 26.1 in bad times and 20 in good times. Second, I use log real federal tax revenues. In that case, the F-statistic is 14.7 in bad times and 12.3 in good times.\footnote{I prefer the ATR over log real tax revenues because it corresponds more closely to a policy instrument. Political discourse usually focuses on changes in tax rates rather than changes in tax revenues. I prefer the ATR over the AMTR as it allows me to use quarterly data. The results are robust to using the alternative tax measures instead.}
In all cases, the narrative measure passes Staiger and Stock’s (1997) $F > 10$ rule-of-thumb for instrument relevance.\textsuperscript{22} However, Olea and Pflueger (2013) show that the threshold can be different when errors are serially correlated. Using the Olea and Pflueger (2013) thresholds, I can not reject that the TSLS bias exceeds 10% of the OLS bias at the 5% level. To address the issue, I also conduct key hypothesis tests using Anderson and Rubin (1949) statistics. These are robust to weak instruments but have low power. In most cases, these statistics point to the same significance level as the Driscoll and Kraay (1998) method described above. Thus, I report statistics based on the Driscoll and Kraay (1998) method and only report Anderson and Rubin (1949) statistics when the two methods point to different significance levels.

3.2 Average Effects of Tax Changes

I first consider the linear model in (1). I estimate impulse responses to a tax shock over twelve quarters, i.e. $H = 12$. Figure 3 presents the results. The plain line shows the point estimates of $\theta_h$ and the shaded areas are 90% confidence bands. I find that a tax shock has no significant impact on output. Over time, output gradually decreases and bottoms out seven quarters after the tax shock 2% below its trend. The result falls in the mid-range of estimated effects of a tax shock on output and is in line with Mertens and Ravn (2011) and Perotti (2012).\textsuperscript{23} Importantly, I find that a tax shock has no significant effect on government spending. This suggests that the effect on output is not driven by an endogenous response of government spending to a tax shock. The average tax rate increases on impact by about 0.5 percentage points, remains roughly constant over the next five quarters and then converges slowly back to its trend level.

3.3 State-Dependent Effects of Tax Changes

I now estimate the state-dependent model in (3). Figure 4 presents the results. The left column shows the impulse responses to a tax shock that hits in bad times and the right column the impulse responses to a shock that hits in good times. The plain lines are the point estimates of $\theta^B_h$ and $\theta^G_h$ and the shaded areas are again 90% confidence bands. To ease orientation, the dashed lines show the point estimates of the linear model $\theta_h$. The effect of a tax shock on output depends crucially on the state of the economy. A tax shock that hits in bad times has no significant effect on output over the entire impulse response horizon. The peak effect is $\min(\hat{\theta}^B_h) = -0.5\%$ with a standard error of 1.3. A tax shock that hits in good times, on the other hand, has a much stronger effect on output than the linear model suggests. The point estimate of $\theta^G_h$ is consistently below that of $\theta_h$ over the entire impulse horizon. The peak effect is $\min(\hat{\theta}^G_h) = -3.5\%$ after seven quarters and is significant at the 1\% level with a standard error of 1.0. To formally assess whether the effects are different in good times and bad, I test the null hypothesis that the peak effects are the same in both states, i.e. $H_0: \min(\theta^B_h) - \min(\theta^G_h) = 0$. The point estimate of the difference is 3.0 percentage points and is significant at the 5\% level with a standard error of 1.5. I find no evidence that the state-dependent effects on output are

\textsuperscript{22}That is the null hypothesis that the instrument is weak is rejected if $F > 10$.

\textsuperscript{23}Blanchard and Perotti (2002) and Favero and Giavazzi (2012) find a peak effect on output close to 1\% while RR and Mertens and Ravn (2014) report values close to 3\%. 
driven by a state-dependent response of government spending. A tax shock has no significant effect on government spending in both states. The impulse responses of the average tax rate are approximately symmetrical across states. Tax shocks have the same scale in good times and bad. Thus, the effect on impact is identical across states. If the shock hits in bad times, ATR increases further in the two quarters following the tax shock, while it remains roughly constant if the shock hits in good times. These differences are, however, not statistically significant. The impulse responses for the average tax rate, therefore, suggest that the state-dependent effects on output are not driven by larger or more persistent tax shocks in good times.

3.4 Alternative Identification Strategy

I now study whether the result is robust to using the Blanchard and Perotti (2002, henceforth BP) identification strategy instead. The specification is identical to BP, but additionally allows for state-dependent effects of tax shocks:

\[ X_t = I_{t-1} A^B X_{t-1} + (1 - I_{t-1}) A^G X_{t-1} + \delta D_t + u_t \]

\[ u_t = I_{t-1} C^B \epsilon_t + (1 - I_{t-1}) C^G \epsilon_t \]

\[ \Sigma_t = I_{t-1} \Sigma_u^B + (1 - I_{t-1}) \Sigma_u^G. \]

\[ X_t = [T_t, G_t, Y_t]' \]

where \( T_t \) are log real federal government revenues. \( X_{t-1} = [X_{t-1}', ..., X_{t-4}'] \). \( D_t \) contains a quadratic trend and a dummy for 1975Q2. \( \epsilon_t \) is the vector of structural shocks with \( E(\epsilon_t) = 0 \) and \( E(\epsilon_t \epsilon_s') = 0 \) for \( s \neq t \). \( u_t = [u_t^T, u_t^G, u_t^Y]' \) are the reduced form residuals with \( u_t \sim N(0, \Sigma_t) \). BP argue that taxes and output have no contemporaneous effect on government spending, because the government is unable to adjust its spending in response to changes in fiscal and macroeconomic conditions in the short run. Thus, \( c_{j1} = c_{j3} = 0 \) for \( j = \{B, G\} \). BP follow the approach of Giorno et al. (1995) to estimate the within-quarter elasticity of net taxes with respect to output. I adapt the approach and estimate the elasticity for two subsamples. To obtain an estimate for \( c_{B13} \), I use the subset of periods in which \( U_{t-1} > 6.5 \). To obtain an estimate for \( c_{G13} \), I use the subset of periods in which \( U_{t-1} \leq 6.5 \). The remaining parameters are estimated from (4). To construct impulse responses from a state-dependent VAR, one needs to impose additional assumptions on how the shock affects the state.\(^{24}\) I follow the standard approach in the literature and assume that the state is constant over the impulse response horizon.\(^{25}\)

I estimate \( c_{G13} = 2.8 \) in good times, and \( c_{B13} = 0.7 \) in bad times.\(^{26}\) Thus, automatic stabilizers lead to a stronger adjustment in taxes in response to a change in output in good times. A possible explanation is that the regular income tax applies to fewer agents in bad times, due to lower levels of employment and the alternative minimum tax (AMT).\(^{27}\) Figure 5 presents the

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\(^{24}\)Appendix A clarifies this point analytically.

\(^{25}\)See for instance Auerbach and Gorodnichenko (2012b) and Ramey and Zubairy (2016).

\(^{26}\)I estimate a value of 2.3 over the full sample, which is slightly larger than BP’s 2.1. The discrepancy is due to different sample horizons. The elasticity is increasing over time and my sample is longer. A higher estimate of the elasticity translates into larger effects of a tax shock on output, see the discussion in Caldara and Kamps (2017).

\(^{27}\)The classic automatic stabilizers are the personal and the corporate income tax system. Because they are progressive in the U.S., a decline in income should be accompanied by a more than proportionate decline in taxes.
impulse responses estimates. Shaded areas are 90% confidence bands, that I compute with a recursive wild bootstrap using 10,000 replications, see Gonçalves and Kilian (2004). Following Mertens and Ravn (2014), I scale the size of the tax shock such that the initial increase in tax revenues equals 1% of GDP. To ease orientation, the dashed lines show the estimates from a linear VAR. The results are similar to those of the baseline specification. I find that a tax shock has no significant effect on output in bad times. The peak effect is $\min(\hat{\theta}_h^B) = -0.5\%$ with a standard error of 0.8. In good times, on the other hand, a tax shock has much stronger effects on output than the linear model suggests. I estimate a peak effect of $\hat{\theta}_h^G = -2.7\%$ which is significant at the 1% level with a standard error of 0.7. The difference in peak effects is $\min(\hat{\theta}_h^B) - \min(\hat{\theta}_h^G) = 2.2$ percentage points, and is significant at the 10% level with a standard error of 1.2. A tax shock has no significant effect on government spending in both states and the impulse responses of the average tax rate are approximately symmetrical across states.

Table 2 collects the estimated peak effects of a tax shock on output using the baseline specification (LP-IV) and the BP VAR. Both approaches suggest that tax shocks have large effects on output only in good times. While the results are qualitatively similar, the VAR estimates are a degree of magnitude smaller. A possible explanation for this is the tight dynamic structure VARs impose on the shape of the impulse response function relative to LPs.

3.5 Sensitivity Analysis

This section performs a sensitivity analysis. Appendix B describes the robustness checks in detail. I discuss them here in a compressed manner.

State Variable.—I explore whether the results are robust to using alternative state variables. First, I allow for a time-varying threshold and consider deviations from the Hodrick-Prescott filtered unemployment rate, using three different smoothing parameters. Second, I use the continuous unemployment rate. Third, I consider two business cycle indicators: NBER recessions and Auerbach and Gorodnichenko’s (2012) smooth transition function of output growth. The peak effects of a tax shock on output are summarized in Table 3. The main finding is robust to using alternative state variables. In all cases, the peak effect of a tax shock on output is larger in good times. The difference in peak effects $\min(\hat{\theta}_h^B) - \min(\hat{\theta}_h^G)$ is significant at the 5% in five out of seven cases, and significant at the 10% level in six out of seven cases.

Controls.—I check that the results are robust to adding additional controls. First, I add four lags of real federal government debt to the public. Second, I aim to control for monetary policy and add four lags of the federal funds rate, the log CPI price level, and log non-borrowed reserves. Third, I follow Mertens and Ravn (2014) to address the possibility of fiscal foresight. I add contemporaneous values and four lags of (i) the implicit tax rate, a measure of expected future taxes that is implied by tax exempt municipal bond yields and perfect arbitrage, constructed by Leeper et al. (2011); (ii) defense stock returns, a series for the accumulated excess returns of large U.S. military contractors constructed by Fisher and Peters (2010); (iii) defense news, Importantly, taxpayers pay the higher of the regular income tax or the AMT. The AMT is imposed at a nearly flat rate on taxable income. In bad times a higher fraction of taxpayers pays the AMT instead of the regular income tax. Moreover, more people are unemployed and do not pay taxes. Hence, the regular income tax rate applies to fewer agents. Intuitively, any automatic adjustment in regular income tax rates thus has a smaller effect on tax revenues in bad times.
a variable which contains professional forecasters’ projections of the path of future military spending, constructed by Ramey (2011). The results are summarized in Table 4. Expanding the set of controls has little effect on the estimates.

**Trend Assumption.**—I switch to a stochastic trend assumption and express variables in annual growth rates. The impulse responses confirm the findings of the baseline specification. Table 4 reports that the difference in peak effects is significant at the 5% level.

**Econometric method.**—I study whether the findings are robust to using alternative econometric methods. I consider three alternatives: (i) the proxy SVAR proposed by Mertens and Ravn (2014), (ii) a VAR augmented with the RR narrative measure, and (iii) the truncated moving average representation proposed by RR. Table 5 summarizes the results. In all cases, tax shocks have significantly larger effects in good times.

**Outliers.**—I check that the results are not driven by large and rare tax changes. I re-estimate the LP-IV in (3) excluding the largest tax changes in the RR narrative measure one at a time. In all cases, the estimates barely change.

**Sign-Dependence.**—I examine whether tax shocks have sign-dependent effects, that is whether tax increases and reductions have different effects on output. I estimate sign-dependent impulse responses with the LP method. I find that the effects of tax increases and reductions on output are approximately symmetrical. The estimation details are laid out in Appendix B.5.

### 3.6 State-Dependent Effects on Other Macroeconomic Variables

In order to better understand the state-dependent effects of tax shocks on output, I now study the effects on other important macroeconomic aggregates. I estimate impulse responses for log real consumption expenditures $C_t$, log real private investment $I_t$, log hours worked $L_t$, and log average hourly earnings of private employees $W_t$. More precisely, I estimate the state-dependent LP-IV in (3) and add one additional variable at a time. In each step, I also add four lags of the additional variable to the set of controls. For instance, when I estimate the impulse responses for log real consumption expenditures, I set $x_t = C_t$ and add four lags of $C_t$ to $z_t$.

Figure 6 presents the results. To ease orientation, the dashed lines show the point estimates from the linear LP-IV. I find that tax shocks have strongly state-dependent effects on consumption, investment, and employment. In each case, a tax shock has much larger effects in good times. The effects of a tax shock on the average hourly wage are small, statistically insignificant, and do not depend on the state. This finding is interesting because, in standard models of the business cycle, taxes affect the economy through adjustments in the real wage.

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28 Many authors interpret the narrative measure as the tax shock and introduce it as an exogenous regressor in a reduced form VAR. See for example Mertens and Ravn (2011; 2012), Favero and Giavazzi (2012), Perotti (2012).

29 These are the exogenous parts of the 1948 tax cuts passed by the congress over Truman’s veto, the 1964 Kennedy-Johnson tax cuts, the 1981 Reagan tax cuts, the 2001 and 2003 Bush tax cuts, the Social Security Amendments of 1977 and 1983 (tax increases), the Tax Equity and Fiscal Responsibility Act of 1982 (tax increase), and the Omnibus Budget Reconciliation Acts of 1990 and 1993 (tax increases).

30 See Table 1 for a detailed description of the variables and corresponding sources.
3.7 Personal and Corporate Income Tax Changes

In this section, I examine whether the finding is driven by one of the two largest U.S. tax categories. I consider personal income taxes, which account for on average 74% of federal tax revenues, and corporate income taxes, which account for on average 16%. Specifically, I use Mertens and Ravn’s (2013) decomposition of the RR narrative measure into the two categories. They identify 16 corporate income tax changes of which 11 occur in good times and 5 in bad times, and 14 personal income tax changes of which 6 occur in good times and 8 in bad times. Figure 7 plots the narrative measures together with the unemployment rate. While the distribution of tax changes over the states is satisfactory, their small number generates an efficiency problem when using a method as flexible as LP. To address the issue, I develop a new econometric method.

The proposed methodology allows to flexibly combine the advantages of VARs and LPs. A VAR is more efficient when the model is correctly specified. The LP method is more robust to model misspecification. In addition, it can be adapted to allow for state-dependent impulse responses, without taking a stand on how the economy transitions from state to state. In a VAR, one needs to make strong assumptions about how the shocks affect the state variable. My method allows to maintain much the efficiency of the VAR, while relaxing its strong assumptions. Its main idea is to use LPs with informative priors centered around the VAR impulse response function. I refer to the method as VAR-LP.

I first illustrate the method’s main idea through a simple example. Assume we have reason to believe that the economy can be approximated by a VAR(1):

\[ X_t = AX_{t-1} + u_{t+1}. \] (5)

\( X_t \) is a \( n \times 1 \) vector of macro variables. Impulse responses can be calculated by iterating forward on the VAR. Alternatively, they can be estimated via LPs:

\[ X_{t+h} = \beta_hX_{t-1} + v_{t+h} \] (6)

\[ v_{t+h} \sim N(0, \Sigma_h) \] (7)

The corresponding impulse responses from a VAR (VAR-IR) and LPs (LP-IR) are

\[ \text{VAR} - IR(h) = A^{h+1} \] (8)

\[ \text{LP} - IR(h) = \beta_h \] (9)

Note that the two methods are equivalent for \( h = 0 \). To flexibly combine both approaches, I propose the following Bayesian procedure. First, the model is estimated for \( h = 0 \) using uniform priors. Then, for each draw of \( \beta_0 \), the prior for \( \beta_h \) is set such that

\[ \beta_h | \beta_0, \lambda_h \sim N(\beta_0^{h+1}, V_h), \text{ for } h > 0. \] (10)

---

31 I use data from 1950 to 2006 to compute the averages.
32 Appendix A clarifies this point analytically.
33 In independent research, Miranda-Agrippino and Ricco (2017) propose a similar approach to study the of monetary policy shocks. However, they do not consider state-dependent models.
\( \lambda_h \) is a hyperprior at horizon \( h \) that I discuss shortly. If \( V_h \to 0 \), the method recovers the VAR-IR. If \( V_{\beta h} \to \infty \), the method recovers the LP-IR. For each horizon \( h \), I use a standard Minnesota prior:

\[
V_{h,i,j} = \frac{\lambda^2_h \sigma^2_{h,i} \sigma^2_{h,j}}{\sigma^2_{h,j}}. \tag{11}
\]

\( V_{h,i,j} \) is the variance of the coefficient for variable \( j \) in equation \( i \) at horizon \( h \). The hyperprior \( \lambda_h \) determines \( V_h \). \( \lambda_h \) can be understood as describing the confidence we have about the model specification. If we believe the VAR is a good approximation of the DGP, we use a low \( \lambda_h \). The more uncertain we are about the DGP, the higher we set \( \lambda_h \). Finally, I follow Kadiyala and Karlsson (1997) and set the prior for \( \Sigma_h \) to

\[
\Sigma_h \mid \lambda_h \sim IW(\Phi_h, n + 2) \tag{12}
\]

\[
\Phi_h = \text{diag}(\sigma^2_{h,1}, \ldots, \sigma^2_{h,n}). \tag{13}
\]

\( \sigma^2_{h,i} \) is the Newey-West corrected variance of a univariate local projection of variable \( i \) on itself at horizon \( h \). It is straightforward to extend the VAR-LP approach to allow for state-dependent effects. The details are laid out in Appendix C. The main difference is that a higher \( \lambda_h \) also relaxes the assumption that the shock does not cause the economy to transition to another state. The larger \( \lambda_h \), the more we relax the parametric restrictions of the VAR and the closer we move to the LP-IR.

To allow for different effects of corporate and personal income tax shocks, I split the average tax rate \((ATR_t)\) into an average corporate tax rate \((ACITR_t)\) and an average personal income tax rate \((APITR_t)\).\(^{35}\) I estimate following the VAR-LP:

\[
\begin{align*}
X_{t+h} &= I_{t-1} A^B_h X_{t-1} + (1 - I_{t-1}) A^G_h X_{t-1} + \delta_h D_t + u_{t+h} \\
v_{t+h} &\sim N(0, \Sigma_{h,t}) \\
\Sigma_{h,t} &= I_{t-1} \Sigma_{h,B} + (1 - I_{t-1}) \Sigma_{h,G}.
\end{align*} \tag{14}
\]

\( X_t = [APITR_t, ACITR_t, G_t, Y_t] \). \( X_{t-1} = [X_{t-1}, \ldots, X_{t-4}]' \). The corporate income tax narrative measure serves as an instrument for the unobserved corporate income tax shock. The personal income tax narrative measure serves as an instrument for the personal income tax shock.\(^{36}\) I use quarterly data from 1950Q1 to 2006Q4.\(^{37}\) I propose a simple and transparent manner for choosing \( \lambda_h \). Once \( \lambda_h \) reaches some value \( \kappa \), the estimated impulse response coincides with the LP-IR (up to a small error). I set \( \lambda_{H,H} = \kappa \) such that the VAR-LP-IR coincides with the LP-IR at horizon \( h = H \). Recall that, at horizon \( h = 0 \), the VAR-LP-IR coincides with the VAR-IR.

\(^{34}\) For simplicity, I focus on a VAR(1) here. In case of a higher order autoregressive process, this becomes \( V_{h,i,j} = \lambda^2_h \sigma^2_{h,i} \sigma^2_{h,j} / \sigma^2_{h,j} \), where \( l \) denotes the lag.

\(^{35}\) A detailed description of the data and corresponding sources is given in Table 1.

\(^{36}\) The approach is similar to Mertens and Ravn (2013) who use the narrative measures as proxy variables for the tax shocks in a VAR.

\(^{37}\) This is the longest time span for which the decomposition of the narrative measure is available.
At intermediate horizons, I let $\lambda_h$ increase gradually:

$$\lambda_h = \kappa \frac{h}{H}$$  \hspace{1cm} (15)

The setup follows a simple logic. At short horizons, iterated forecasts (VAR-IR) perform well. We can benefit from its high estimator efficiency by setting a low $\lambda_h$. As the horizon grows, the VAR-IR suffers from an increasingly large bias.\(^{38}\) Thus, I increase $\lambda_h$ such that the VAR-LP-IR gradually approaches the LP-IR. The setup also implies that I relax the assumption that the shock does not alter the state of the economy as the horizon grows. This is an intuitive feature. A tax shock likely does not change the state on impact but can unfold dynamics that cause the economy to transition to another state over time.

Figure 8 presents the impulse responses of output to the two types of tax shocks. The plain lines are the mean impulse response estimates. The shaded areas cover 90\% of the posterior probability. To ease orientation, the dashed lines show the mean impulse response estimates from a linear version of (14). The top panels show the effects of a personal income tax shock and the bottom panels show the effects of a corporate income tax shock. I use the same scale for the tax shocks as in the baseline specification.\(^{39}\) I find that both types of tax shocks have strongly state-dependent effects on output. They have a small and insignificant effect on output when they hit in bad times, and large and significant effects when they hit in good times.

4 Theory

This section provides a structural interpretation of the results. I study a simple search model of unemployment with endogenous job-search effort. In the model, the effect of an income tax cut is low when unemployment is high. I focus on income taxes because it is by far the largest tax category. The search-and-matching approach is supported by the empirical evidence. Barro and Redlick (2011) find that tax changes affect output mainly through substitution effects, rather than wealth effects. Consistent with that finding, Keane (2011) surveys the literature on the relationship between taxes and labor supply and concludes that tax cuts have a positive effect on hours worked. However, a well established empirical fact is that most cyclical variations in hours are due to variations in the number of employed workers and not variations in hours per worker (Shimer, 2010). In the textbook real business cycle model and the textbook New Keynesian model, the labor supply decision amounts to choosing hours directly. In a search-and-matching-framework with endogenous job-search effort, on the other hand, workers can only choose the intensity with which they search for a job. Once matched, they do not decide on hours, which is consistent with the empirical evidence. Thus, a tax cut raises labor supply by increasing workers’ job search effort. This is again consistent with the empirical evidence (Gentry and Hubbard, 2004).

First, I perform a comparative steady-states analysis, because it is transparent. It allows for

\(^{38}\)This can be appreciated by returning to Equation 8: a bias in the estimate of $A$ leads to biased impulse response estimates. This error is compounded at longer horizons.

\(^{39}\)I again verify that the $APITR$ and $ACITR$ impulse responses are approximately symmetrical across states. This suggests that the state-dependent effects on output are not driven by larger or more persistent tax shocks in good times.
an analytical expression of the income tax multiplier and can be studied in a diagram. Second, I embed the model into a standard New Keynesian model to quantify the degree of state-dependence the model can generate. In the last part, I discuss the model’s key assumptions and its empirical support.

4.1 Comparative steady-states Analysis

Labor Market. — A measure of identical workers participate in the labor market. A measure of identical firms employ \( L_t \) workers. At the beginning of period \( t \), a fraction \( \lambda \) of the \( L_{t-1} \) existing worker-job matches is exogenously destroyed. Workers who lose their job start to search for a job immediately. At the beginning of period \( t \), \( u_t = 1 - (1 - \lambda)L_{t-1} \) workers search for a job. Each unemployed worker searches for a job with effort \( s_t \). Job seekers who find a job start working in period \( t \) with the \( (1 - \lambda)L_{t-1} \) incumbent workers. The representative firm posts \( v_t \) vacancies to hire workers. The number of matches in period \( t \) is given by a Cobb-Douglas matching function \( m_t = m(s_t u_t)^{\eta}v_t^{1-\eta} \). The parameter \( m \) measures matching effectiveness, and \( \eta \in (0, 1) \) is the elasticity of the matching function with respect to unemployment. Let \( \theta_t \equiv \frac{v_t}{s_t u_t} \) be the labor market tightness. Job seekers who exert search effort \( s_t = 1 \) find a job with probability \( f(\theta_t) = \frac{m u_t}{s_t u_t} = m\theta_t^{1-\eta} \). The firm can fill a vacancy with probability \( q(\theta_t) = \frac{m u_t}{v_t} = m\theta^{-\eta} \). All workers have the same time discount factor \( \beta < 1 \). Given the matching process on the labor market, the employment rate is

\[
L_t = (1 - \lambda) \cdot L_{t-1} + (1 - (1 - \lambda) \cdot L_{t-1}) \cdot s_t \cdot f(\theta_t). \tag{16}
\]

In steady-state, inflows to unemployment \( \lambda L \) equal outflows from unemployment \( (1 - (1 - \lambda)L)s f(\theta) \), and the employment rate is a function of labor market tightness and search effort given by

\[
L^*(\theta, s) = \frac{s \cdot f(\theta)}{\lambda + (1 - \lambda) \cdot s \cdot f(\theta)}. \tag{17}
\]

Following Michaillat (2014), I refer to this function as quasi-labor supply.\(^{40}\) It translates the search decision of workers into the employment rate that prevails when the labor market is in steady-state. The quasi-labor supply is thus similar to a conventional labor supply function in that it gives the quantity of labor arising from workers’ optimal choice based on prevailing economic conditions, especially the return of work relative to non-work (leisure versus job search). However, there is one difference between the two concepts. A conventional labor supply indicates directly workers’ optimal employment choice (number of hours, or number of workers with indivisible labor). But in the presence of matching frictions, workers cannot directly choose how much they work. They can only choose how much they search for jobs when they are unemployed. Therefore, the quasi-labor supply indicates the steady-state employment rate that prevails when workers’ search effort is optimal. Lemma 1 establishes a few properties of the quasi-labor supply:

\(^{40}\)Workers do not choose hours worked directly. This is consistent with the empirical evidence: (i) most cyclical variation in total hours worked is due to variation in number of employed workers, and not in variation in hours per worker; and (ii) most cyclical variation in unemployment is due to variation in number of employed workers, and not variation in number of labor force participants (Shimer, 2010).
LEMMA 1: \( L^s(\theta, s) \) is strictly increasing and strictly concave in \( \theta \) and \( s \), \( \lim_{\theta \to 0} L^s(\theta, s) = 0 \), \( \lim_{\theta \to \infty} L^s(\theta, s) = 1 \).

This follows from the properties of \( f(\theta) \). The lemma says that when labor market flows are balanced and labor market tightness is high, employment is high. The reason is that job seekers find jobs quickly when tightness is high. Moreover, if search effort is high, employment is high. The reason is that job seekers find jobs quickly when they exert high search effort.

**Firms.**—Firms produce a final good and sell it on a perfectly competitive market. A representative firm uses labor \( L_t \) to produce output \( Y_t \) according to the production function \( Y_t = A_t \cdot L_t^\alpha \), where \( \alpha \in (0, 1) \) measures diminishing marginal returns to labor. \( A_t \) is the firms’ technology. A risk neutral entrepreneur, with the same discount factor \( \beta < 1 \) as workers, owns the firm and consumes all profits. Thus, \( C^f_t = \phi_t \). The firm pays a real wage \( w_t \) to its employees. In addition, the firm incurs a cost to hire workers. In period \( t \), the firm hires \( H_t = L_t - (1 - \lambda) \cdot L_{t-1} \) workers. Posting a vacancy for one period costs \( A_tr > 0 \) units of the final good.\(^{41}\) \( r \) measures resources spent recruiting workers. A firm can hire a worker with certainty by opening \( \frac{w}{q(\theta)} \) vacancies and spending \( \frac{A_tr}{q(\theta)} \). Hence, the firm’s real profits \( \phi_t \) at time \( t \) are

\[
\phi_t = A_t \cdot L_t^\alpha - w_t \cdot L_t - \frac{A_t \cdot r}{q(\theta)} \cdot H_t. \tag{18}
\]

Taking \( \{\theta_t\}_{t=0}^\infty \) and \( \{w_t\}_{t=0}^\infty \) as given, the firm chooses \( \{L_t\}_{t=0}^\infty \) to maximize the discounted sum of real profits. In steady-state, the optimal employment choice satisfies

\[
\alpha \cdot A \cdot L_t^{\alpha-1} = w + [1 - \beta \cdot (1 - \lambda)] \cdot \frac{r \cdot A}{q(\theta)}. \tag{19}
\]

The firm hires labor until the marginal product of labor, \( A \cdot \alpha \cdot L_t^{\alpha-1} \), equals the marginal cost of labor, which is the sum of the real wage, \( w \), plus the amortized hiring cost \([1 - \beta \cdot (1 - \lambda)] \cdot \frac{r \cdot A}{q(\theta)}\). Labor demand is the employment level that solves (19), expressed as a function of tightness and the real wage:

\[
L^d(\theta, w) = \left[ \frac{1}{\alpha} \cdot \left( \frac{w}{A} + [1 - \beta \cdot (1 - \lambda)] \cdot \frac{r}{q(\theta)} \right) \right]^{\frac{1}{\alpha-1}}.
\]

Lemma 2 establishes a few properties of the aggregate labor demand.

**LEMMA 2:** The function \( L^d(\theta, w) \) is strictly decreasing in \( \theta \) and \( w \), and strictly increasing in \( A \), \( \lim_{\theta \to \infty} L^d(\theta, w) = 0 \), and \( \lim_{\theta \to 0} L^d(\theta, w) = L^* \), where \( L^* = \left[ \frac{w}{\alpha \cdot A} \right]^{\frac{1}{\alpha-1}} \).

This follows from the properties of \( q(\theta) \). The lemma says that labor demand is low when the real wage is high, labor market tightness is high, or technology is low. The intuition is

\(^{41}\)As in Pissarides (2000), the cost of opening a vacancy is proportional to technology \( A_t \). This is equivalent to assuming that the recruiting technology is independent of technology, but uses labor as unique input (Shimer, 2010). This assumption is appealing since recruiting is a time-intensive activity.
that when the real wage is high, labor market tightness is high, and technology is low, the marginal cost of labor is high. The quantity \( \min(L^*, 1) \) is the employment rate that prevails if the recruiting cost is \( r = 0 \). If \( L^* < 1 \), the labor market does not converge to full employment when the recruiting cost converges to 0; jobs are rationed if \( w > \alpha \cdot A \). In equilibrium, firms are always on their demand curve, that is \( L = L^d(\theta, w) \). Since labor demand is strictly decreasing in \( \theta \) and \( w \) and strictly increasing in \( A \), steady-state profits \( \phi \) are strictly decreasing in \( \theta \) and \( w \) and strictly increasing in \( A \).

Workers.—Employed workers receive a real wage \( w_t \) and lump-sum transfers \( T_t \), and pay an income tax \( \tau_t \). Unemployed workers receive lump-sum transfers \( T_t \). Workers cannot borrow or save. Thus, an employed worker consumes \( C_t^e = w_t - \tau_t + T_t \). An unemployed worker consumes \( C_t^u = T_t \). The utility from consumption is \( U(C_t) = C_t \).

The disutility from job search is \( \Psi(s_t) = \delta \cdot \frac{\kappa}{1 + \kappa} \cdot s_t^{\frac{\kappa+1}{\kappa}} \). The parameter \( \delta \) governs the level of disutility, and \( \kappa < 1 \) governs the convexity of the disutility function. Thus, the worker’s utility at time \( t \) is:

\[
(1 - L_t^e) \cdot U(C_t^u) + L_t^e \cdot U(C_t^e) - [1 - (1 - \lambda) \cdot L_{t-1}^e] \cdot \Psi(s_t)
\]

Taking \( \{\theta_t\}_t^{\infty}, \{w_t\}_t^{\infty}, \{\tau_t\}_t^{\infty} \) as given, the worker chooses \( \{s_t\}_t^{\infty} \) to maximize utility subject to the probability of being employed in the next period: \( L_t^e = (1 - \lambda) \cdot L_{t-1}^e + (1 - (1 - \lambda) \cdot L_{t-1}^e) \cdot s_t \cdot f(\theta_t) \). In steady-state, the optimal search effort satisfies

\[
[1 - \beta \cdot (1 - \lambda)] \cdot \frac{\Psi'(s)}{f(\theta)} + \frac{1 + \kappa}{\kappa} \cdot \beta \cdot (1 - \lambda) \cdot \Psi(s) = \Delta U.
\]

This equation implicitly defines the optimal supply of search effort \( s^*(\theta, \tau) \). \( s^*(\theta, \tau) \) is strictly increasing and concave in \( \theta \) and \( \Delta U \). Search effort is increasing in labor market tightness, because a higher \( \theta \) implies a higher job-finding probability \( f(\theta) \). Search effort is decreasing in income taxes, because a higher \( \tau \) implies a lower utility gain from work \( \Delta U \). Moreover, I have that \( -\partial s^*(\theta, \tau)/\partial \theta > 0 \). Thus, the effect of a tax cut on search effort is larger when labor market tightness is high. The reason is that workers internalize the job-finding probability when choosing the optimal search effort. Combining \( s^*(\theta, \tau) \) with (17) defines the aggregate quasi-labor supply with endogenous search effort.

\[
L^s(\theta, \tau) = \frac{s^*(\theta, \tau) \cdot f(\theta)}{\lambda + (1 - \lambda) \cdot s^*(\theta, \tau) \cdot f(\theta)}.
\]

Lemma 3 establishes a few properties of the aggregate quasi-labor supply.

**Lemma 3:** The function \( L^s(\theta, \tau) \) is strictly increasing and strictly concave in \( \theta \) and \( -\tau \),

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42 The linear utility function simplifies derivations. I relax the assumption and use a concave utility function in the numerical analysis of the model.

43 The model closely follows Landais et al. (2016b). Other papers give household control over future employment through the allocation of non-employed workers between unemployment, which allows workers to find jobs, and inactivity out of the labor force, which provides leisure (see for example Brückner and Pappa, 2012). Both approaches are broadly equivalent for this application.
\[\lim_{\theta \to \infty} L^*(\theta, \tau) = 1, \text{ and } \lim_{\theta \to 0} L^*(\theta, \tau) = 0.\]

This follows from the properties of \( f(\theta) \) and \( s^*(\theta, \tau) \). The lemma says that when labor market flows are balanced and labor market tightness is high, employment is high. The reason is that job seekers search more for jobs and find jobs more quickly when tightness is high. Moreover, if income taxes are high, employment is low. The reason is that job seekers search less for jobs when the utility gain from work is low.

**Real Wage.**—As in Hall (2005), I assume that the real wage \( w_t \) is exogenous.\(^4\) Assuming an exogenous real wage resolves the indeterminacy of wages that arise in search-and-matching models. This situation arises because worker and firm must share a positive surplus, created by their matching. The positive surplus arises because the firm’s marginal product of labor always exceeds the worker’s flow value of unemployment when they match. In the steady-state equilibrium, the firm’s hiring decisions impose that the real wage falls between the marginal product of labor and the flow value of unemployment; therefore, the real wage is necessarily pairwise Pareto efficient.

**Government.**—The government balances its budget each period. It distributes lump-sum transfers \( T_t \). To finance this, the government levies a labor income tax that yields \( \tau_t \cdot L_t \). Thus, \( T_t = \tau_t \cdot L_t \). Combining the government’s, the entrepreneur’s, and workers’ budget yields the aggregate resource constraint
\[
C_t = w_t \cdot L_t + \phi_t = Y_t - r \cdot A_t q^*(\theta_t).
\]
The final good is consumed or allocated to hiring workers.

**Steady-state equilibrium**

I now solve for the steady-state equilibrium of the model, taking as given the real wage \( w \) and government tax policy \( \tau \). The equilibrium consists of two endogenous variables: aggregate employment \( L \), and labor market tightness \( \theta \). Equilibrium labor market tightness equalizes quasi-labor supply and aggregate labor demand:
\[
L^*(\theta, \tau) = L^d(\theta, A). \tag{24}
\]
Equilibrium employment is obtained from aggregate labor supply:
\[
L = L^*(\theta, \tau). \tag{25}
\]
where \( \theta \) satisfies (24). Lemma 2 and 3 imply that the equilibrium exists and is unique. Figure 9 Panel (a) shows the equilibrium in a \((L, \theta)\) plane. The quasi-labor supply curve is upward-sloping and convex. The aggregate labor demand curve is downward sloping and convex. The labor demand curve intersects the x-axis at \( L^* \). Quasi-labor supply curve and labor demand curve intersect at the equilibrium point. Equilibrium is achieved through vacancy posting. For

\(^4\)A high degree of real wage rigidity is consistent with the empirical evidence (Card and Hyslop, 1997; Blanchard and Katz, 1997).
instance, if labor demand is greater than quasi-labor supply, firms post additional vacancies to hire more workers. More jobseekers find a job and the unemployment rate declines. In turn, labor market tightness increases, the vacancy-filling rate declines, and hiring costs increase. As a result, the number of workers desired by firms falls and the gap between supply and demand diminishes. The process continues until the gap between supply and demand is closed.

**Low-unemployment and high-unemployment steady-states**

I study steady-state equilibria that differ by the value of technology $A$. This comparative steady-states analysis is useful because it closely resembles the analysis of business cycles that are driven by technology or demand shocks in the presence of real wage rigidities. I interpret a steady-state with a low $A$ as bad times, and a steady-state with a high $A$ as good times. Lemma 4 establishes how the labor market changes across steady-state equilibria that are characterized by different values of $A$.

**LEMMA 4:** The labor market variables satisfy $\frac{d\theta}{dA} > 0$, $\frac{dL}{dA} > 0$, and $\frac{du}{dA} < 0$

Lemma 4 says that in bad times, labor market tightness and employment are low, and unemployment is high. Appendix D contains the proof of the lemma, but the main idea can be appreciated graphically by comparing the steady-state with a low $A$ shown in Figure 9 Panel (a) to the steady-state with a high $A$ shown in Figure 9 Panel (b). In the low $A$ steady-state, the aggregate labor demand is depressed. The labor demand curve is located inward. Thus, in equilibrium, labor market tightness and employment are low, and unemployment is high. The low $A$ mimics bad times, and the high $A$ steady-state mimics bad times.

**Income tax multiplier**

I start from a steady-state, cut the income tax, compute the new steady-state, and compare employment in the two steady-states. Then, I examine how the effect on employment depends on the value $A$ in the initial steady-state. I measure the difference in employment between the two steady-states by the multiplier

$$M \equiv -\frac{\partial L}{\partial \tau}. \quad (26)$$

Proposition 1 establishes some properties of the income tax multiplier.$^{45}$

**PROPOSITION 1:** The income tax multiplier $M$ satisfies

(i) $M > 0$;

(ii) $\frac{dM}{dA} > 0$.

Part (i) shows that the multiplier is positive. An income tax cut increases employment. The

---

$^{45}$I focus on an employment multiplier instead of an output multiplier to reduce notation. The output multiplier is $M^Y = -dY/d\tau = \alpha \cdot M \cdot L^{-1}$. Proposition 1 also applies to $M^Y$. Hence, (i) $M^Y > 0$ and (ii) $dM^Y/dA > 0$. I proof this in Appendix D.
result is illustrated in Figure 9 Panel (c). A tax cut increases the utility gain from work. This increases job-search effort by jobseekers and the quasi-labor supply curve shifts outwards. At the current tightness, labor demand falls short of quasi-labor supply. To reach a new equilibrium, tightness decreases. Thus, the vacancy-filling rate rises and hiring cost falls. As a consequence, firms increase employment and produce more of the final good. The effect of a tax cut on employment and output is determined by the amplitude of the reduction in tightness and hiring cost. Appendix D proves part (i).

Part (ii) shows that the multiplier is higher in steady-states in which $A$ is high. This is illustrated by comparing the low $A$ steady-state in Figure 9 Panel (c) to the high $A$ steady-state in Figure 9 Panel (d).

In the low $A$ steady-state, the quasi-labor supply is flat at the equilibrium point. Thus, a shift in the quasi-labor supply curve following a tax cut has a small effect on labor market tightness and employment. When labor demand is low and unemployment is high, firms need fewer vacancies to hire an additional worker, because the matching process is congested by jobseekers. The number of jobseekers per vacancy is so large that additional search effort has little influence on tightness. Moreover, the effect of a tax cut on search effort is smaller, because workers internalize that the job-finding probability is low. Consequently, the reduction in tightness and the effect on output are small.

In the high $A$ steady-state, the quasi-labor supply is steep at the equilibrium point. Thus, a shift in the quasi-labor supply following a tax cut has a large effect on labor market tightness and employment. When labor demand is high and unemployment is low, firms need more vacancies to hire an additional worker, because the matching process is congested by vacancies. The number of jobseekers per vacancy is so small that an increase in search effort leads to a large increase in the vacancy-filling rate. Moreover, the effect of a tax cut on search effort is larger, because workers internalize that the job-finding probability is high. Thus, the reduction in tightness and the effect on output are large.

The proof of proposition 1 is in Appendix D, but I provide a brief version here. Let $\epsilon^s \equiv (\partial L^s / \partial \tau) \cdot (\theta / L^s) > 0$ and $\epsilon^d \equiv -(\partial L^d / \partial \tau) \cdot (\theta / L^d) > 0$ be the elasticities of quasi-labor supply and labor demand with respect to tightness. Implicit differentiation of the equilibrium conditions (24) and (25) yields the multiplier:

$$M = -\frac{\partial L^s}{\partial \tau} \cdot \frac{1}{1 + (\epsilon^s/\epsilon^d)}. \quad (27)$$

The multiplier is positive because $\partial L^s / \partial \tau < 0$, and $\epsilon^s$ and $\epsilon^d$ are both finite. A tax cut raises the utility gain from work and thus stimulates jobseekers’ job-search effort and quasi-labor supply. The proof shows that $\epsilon^d$ and $-\partial L^s / \partial \tau$ are increasing in $A$, and $\epsilon^s$ is decreasing in $A$. Hence, $M$ is increasing in $A$. The multiplier is high when the quasi-labor supply is steep and the labor demand is flat. In addition, the multiplier is high when the effect of job-search on employment is high, which is the case when firms have many vacancies to fill.
4.2 Dynamic Multiplier

The goal of this part is to quantify the degree of state-dependence the model can generate. I use simulations to explore the effect of a personal income tax cut at different stages of the business cycle. To improve realism, the search-and-matching model of the previous section is embedded into a New Keynesian model. Simulations of this model calibrated to US data confirm the steady-state results. The income tax multiplier is positive and strongly procyclical.

I start from the New Keynesian model with search-and-matching frictions laid out by Michaillat (2014). I depart from his model in two ways. First, I abstract from government employment policies and focus on tax policy. Second, I adapt the model to allow for endogenous job-search effort.

The model departs from the textbook New Keynesian model in two ways. First, monopolistic firms are subject to the quadratic price adjustment cost of Rotemberg (1982) instead of the price-setting friction of Calvo (1983). Thus, the model admits a closed-form expression for the Philips-curve, which simplifies simulations. Second, the labor market is not perfectly competitive but adopts the search-and-matching structure described above. This introduces four modifications to the standard New Keynesian model. First, the labor supply is replaced by the quasi-labor supply. Second, firms’ labor demand accounts for hiring cost. Third, the model counts one more variable, labor market tightness, which is determined by the equality of labor demand and quasi-labor supply. Fourth, the model counts one more equation, a rule that determines the real wage. I relegate the model derivations to Appendix E. Here, I focus on key features and differences to the small search-and-matching model.

Business Cycle.—Business cycles are driven by technology, modeled as a stochastic process \( \{A_t\}_{t=0}^{\infty} \).

Labor Market.—Workers are employed by intermediate good firms indexed by \( i \in [0,1] \). Firm \( i \) employs \( L_t(i) \) workers. Employment is \( L_t = \int_0^1 L_t(i)di \).

Large Household.—All workers are part of a large household. In addition to job-search effort, the household chooses between consumption and saving to maximize utility, subject to a budget constraint and a no-Ponzi-game condition. The household saves by investing in risk-free government bonds. Labor income is subject to a proportional income tax \( \tau_t \). Let \( \pi_t \equiv (P_t/P_{t-1}) - 1 \) be the inflation rate at time \( t \). The household’s optimal consumption path is given by the Euler equation

\[
C_t = \beta \cdot E_t \left[ \frac{R_t}{1 + \pi_{t+1}} \cdot C_{t+1} \right].
\]

The household’s optimal search path is given by:

\[
\frac{\Psi'(s_t)}{f(\theta_t)} - \beta \cdot (1 - \lambda) \cdot E_t \left[ \Psi'(s_{t+1}) \cdot \frac{1}{f(\theta_{t+1})} \cdot [1 - s_{t+1} \cdot f(\theta_{t+1})] \right] = \Delta U_t
\]

This equation implicitly defines optimal search effort as an increasing function of labor market...
tightness \( \theta_t \) and the utility gain from work \( \Delta U_t \). The search path \( E_t \frac{s_{t+1}}{s_t} \) is increasing in the expected job-finding probability in the future relative to today \( E_t f(\theta_{t+1})/f(\theta_t) \).

**Final Good Firms.**—A measure 1 of identical firms produce the final good and sell it in a perfectly competitive market. The representative final good firm uses \( y_t(i) \) units of each intermediate good \( i \in [0, 1] \) to produce \( Y_t \) units of final good.

**Intermediate Good Firms.**—There is no entry or exit in the intermediate good section. Each intermediate good is produced by a monopolist. The monopolist uses \( L_t(i) \) units of labor to produce \( y_t(i) \) units of intermediate good \( i \) according to the production function \( y_t(i) = A_t \cdot L_t(i)^{\alpha} \). In addition to the hiring cost of the search-and-matching model, the monopolist incurs a cost to adjust its nominal price, following Rotemberg (1982)

\[
\frac{\gamma}{2} \cdot \left( \frac{p_t(i)}{p_{t-1}(i)} - 1 \right)^2 \cdot C_t, \tag{30}
\]

where \( \gamma \) captures the amount of resources devoted to adjusting prices. The price-adjustment cost is measured in units of the final good. It increases proportionally with the size of the economy, measured by \( C_t \).

**Real Wage.**—As in Blanchard and Galí (2010), the real wage is a simple function of technology:

\[
w_t = \omega A_t^{\nu}. \tag{31}\]

\( \omega \) governs the level of the real wage, and \( \nu \) the response to technology. I assume that the real wage is somewhat rigid. Thus, \( \nu < 1 \).

**Monetary Policy.**—Monetary policy sets the gross nominal interest rate to

\[
R_t = \beta^{-1} \cdot (1 + \pi_t)^{\phi_{\pi}(1-\rho_R)} \cdot (\beta \cdot R_{t-1})^{\rho_R} \tag{32}
\]

\( \rho_R \) measures interest-rate smoothing. \( \phi_{\pi} > 1 \) measures the response of monetary policy to inflation. I assume that steady-state inflation is \( \pi = 0 \). The steady-state gross nominal interest rate is \( \beta^{-1} \).

**Government.**—The government distributes lump-sum taxes \( T_t \) and services debt from the previous period, which costs \( R_{t-1}D_{t-1} \). To finance this, it collects proportional labor income taxes, which yields \( w_t \cdot \tau_t \cdot L_t \) and issues new debt \( D_t \). Thus, the budget constraint becomes

\[
T_t + R_{t-1} \cdot D_{t-1} = w_t \cdot \tau_t \cdot L_t + R_t. \tag{33}
\]

Using the household’s budget constraint and the definition of profits, I rewrite the government’s
budget constraint as an aggregate resource constraint

\[ Y_t = C_t \cdot \left(1 + \frac{\gamma}{2} \cdot \pi_t^2\right) + \frac{r \cdot A_t}{q(\theta_t)} \cdot H_t. \]  

(34)

The resource constraint says that the final good is consumed, allocated to changing prices, or allocated to hiring workers.

**Symmetric Equilibrium.**—In a symmetric equilibrium, all intermediate good firms are identical. Thus, \( L_t(i) = L_t \), \( y_t(i) = Y_t \), \( p_t(i) = P_t \), and \( \mu_t(i) = \mu_t \), where \( \mu_t(i) \) is the marginal revenue of producing one good of intermediate good \( i \) in period \( t \). Using the symmetry assumption, I derive aggregate labor from monopolists’ labor demand:

\[ s\mu_t \cdot \alpha \cdot L_t^{\alpha-1} = \frac{w_t}{A_t} + \frac{r}{q(\theta_t)} - \beta \cdot (1 - \lambda) \cdot E_t \left[ \frac{C_t}{A_{t+1}} \cdot \frac{A_{t+1}}{A_t} \cdot \frac{r}{q(\theta_{t+1})} \right]. \]  

(35)

The Philips curve is derived from monopolists’ optimal price setting equation:

\[ \pi_t \cdot (\pi_t + 1) = \frac{1}{\gamma} \cdot \frac{Y_t}{C_t} \cdot [\epsilon \cdot \mu_t - (\epsilon - 1)] + \beta \cdot E_t [\pi_{t+1} \cdot (\pi_{t+1} + 1)]. \]  

(36)

The aggregate production function is derived from the monopolists’ production function:

\[ Y_t = A_t \cdot L_t^\alpha. \]  

(37)

The zero-inflation steady-state is isomorphic to the search-and-matching model in the previous section. The steady-state of the New Keynesian model is given by the intersection of the quasi-labor supply and the aggregate labor demand. In steady-state, the optimal search effort is still given by (22). The quasi-labor supply is still given by (23). With zero inflation, the Philips curve implies that \( \mu = (\epsilon - 1)/\epsilon \). Hence, firms’ labor demand satisfies (20) except for one change. The marginal cost of labor is multiplied by a markup \( 1/\mu = \epsilon/(\epsilon - 1) > 1 \) because intermediate good firms have monopoly power. With some wage rigidity \( \nu < 1 \), the ratio \( w/a = \omega A^\nu - 1 \) decreases when technology increases. Therefore, a steady-state with high \( A \) still corresponds to a steady-state with high labor demand and low unemployment.

The model has two shocks. A technology shock and a tax shock. I assume the stochastic processes.

\[ \log(A_t) = \rho_A \cdot \log(A_{t-1}) + \epsilon_t^A, \]  

(38)

\[ \tau_t - \tau = \rho_{\tau} \cdot (\tau_{t-1} - \tau) + \epsilon_t^\tau, \]  

(39)

where \( \tau \) is the steady-state level of taxes. \( |\rho_A| < 1 \), and \( |\rho_{\tau}| < 1 \) describe the persistence of the shocks. I assume that technology shocks and tax shocks are uncorrelated. A technology shock has the scale \( \sigma_A \). A tax shock has the scale \( \sigma_{\tau} \).

**Calibration**
I calibrate the model to US data. To enhance transparency, I use the exact same parameter values as Michaillat (2014). To calibrate the parameters relating to job-search effort, I follow Landais et al. (2016a). Thus, I set the parameter governing the convexity of the disutility from search to $\kappa = 0.22$. I set the level of disutility to $\delta = 0.33$ to match a steady-state search effort of $s = 1$. I set $\tau = 0.26$, which matches the estimate of the average effective labor income tax rate from Mendoza et al. (1994). Michaillat (2014) calibrates the model to weekly data and sets $\rho_A = 0.992$. I set $\rho_\tau$ to match the empirical impulse response of the average tax rate to a tax shock. This implies a value of 0.896 at quarterly frequency, so I set the weekly autocorrelation to $\rho_\tau = 0.992$. Thus, the persistence of the two shocks is identical. Table 6 summarizes the calibration of all parameters.

Simulations

I use a shooting algorithm to simulate an approximation of the model in which the household and firms have perfect foresight. First, I simulate the effect of a technology shock. In period $t - 1$, the economy is in the steady-state. In period $t$ an unexpected technology shock $\epsilon_t^A = \sigma_A$ hits the economy. No other shock occurs after that. The impulse response at horizon $h$ is given by

$$IRF^A(h) = \left[ x_{t+h} \mid \epsilon_t^A = \sigma_A, \epsilon_t^\tau = 0 \right] - \left[ x_{t+h} \mid \epsilon_t^A = 0, \epsilon_t^\tau = 0 \right], \quad (40)$$

where $x_{t+h}$ is the variable of interest. Second, I simulate an expansion that is accompanied by a tax shock. In period $t - 1$, the economy is in the steady-state. In period $t$ an unexpected technology shock hits $\epsilon_t^A = \sigma_A$ hits the economy. At the same time, an unexpected tax shock $\epsilon_t^\tau = \sigma_\tau$ hits. No other shock occurs after that. The impulse response function is given by

$$IRF^{A+\tau}(h) = \left[ x_{t+h} \mid \epsilon_t^A = \sigma_A, \epsilon_t^\tau = \sigma_\tau \right] - \left[ x_{t+h} \mid \epsilon_t^A = 0, \epsilon_t^\tau = 0 \right], \quad (41)$$

The difference between (41) and (40) is the impulse response function of the tax shock given the state of the economy:

$$IRF^\tau(h) = \left[ x_{t+h} \mid \epsilon_t^A = \sigma_A, \epsilon_t^\tau = \sigma_\tau \right] - \left[ x_{t+h} \mid \epsilon_t^A = \sigma_A, \epsilon_t^\tau = 0 \right]. \quad (42)$$

I simulate impulse responses to a 1 percentage point reduction in the tax rate $\tau_t$. Thus, $\sigma_\tau = 0.01$. I repeat the simulations for a collection of 16 technology shocks ranging from $\sigma_A = -0.036$ to $\sigma_A = +0.054$. I compute impulse responses for three variables: log output, labor market tightness, and the unemployment rate. For each technology shock, I compute the peak effect of a tax cut, and I measure the extremum of the unemployment rate without a tax cut. I link each peak effect to the associated unemployment rate and plot the 16 peak effect-unemployment pairs in Figure 10. The peak effects of a tax cut are strongly procyclical. The peak effect on log output increases from 0.14% when the unemployment rate is 8% to 0.41% when the unemployment rate is 5%. The peak effect on labor market tightness moves from -0.07 to 0.38. The peak effect on unemployment moves from 0.4 percentage points to 1.1 percentage points to 1.1 percentage points.

The impulse responses to a tax cut and a tax increase are approximately symmetrical. This is in line with the empirical evidence presented in Section 3. Thus, I only show results for a tax cut.
points. These results highlight that the model can account for a high degree of state-dependence in the effects of tax shocks.

4.3 Alternative Theories and Empirical Evidence

In this part, I discuss additional evidence that supports (i) the mechanism through which a tax cut affects labor market tightness and employment in the model and (ii) the models’ key assumptions.

The effect of search effort on employment and tightness

In the model, a tax cut increases the job-search effort of jobseekers. This is consistent with the empirical evidence of Gentry and Hubbard (2004). An increase in job-search effort lowers labor market tightness and increases employment. Crépon et al. (2013) provide micro-evidence consistent with the predictions of the model. They analyze a large-scale randomized experiment in France. Some young educated jobseekers are treated by receiving job-search assistance. The experiment has a double-randomization design: (i) some areas are treated and some are not, (ii) within treated areas some jobseekers are treated and some are not. They find that treated jobseekers have a higher job-finding probability than control jobseekers in the same area. Critically, control jobseekers in treated areas have a lower job-finding probability than control jobseekers in control areas. Gautier et al. (2012) obtain similar results from a smaller-scale experiment in Denmark. Both studies find that the presence of jobseekers who search intensely hurts the prospects of other jobseekers in the same labor market. Thus, the evidence supports a model in which an increase in search effort has a negative effect on tightness.

In the model, the effect of an increase in search effort is smaller in bad times. Toohey (2017) exploits variations in job-search requirements across US states and over time and finds evidence in support of the models’ prediction. He finds that when search requirements are more stringent, unemployment insurance recipients search more and find jobs faster. However, increasing search effort has a smaller effect on the unemployment rate in bad times than in good times.

Alternative Theories

The model has two key assumptions: (i) diminishing marginal returns to labor and (ii) a rigid wage. I discuss the importance of these assumptions by considering two well-known alternatives. I again focus on steady-state equilibria as described in Section 4.1. I then argue that the empirical evidence supports my assumptions.

Hall (2005).—In Hall (2005), the wage is fixed and firms produce with constant returns to scale ($\alpha = 1$). The firm’s optimal employment choice solely determines equilibrium labor market tightness. Figure 11 Panel (a) shows the effect of a tax cut in the in bad times and Figure 11 Panel (b) shows the effect of a tax cut in good times. In the diagram, the labor demand is a horizontal line. An increase in $A$ shifts the labor demand upwards. In the high $A$ steady-state, employment and labor market tightness are higher. A tax cut increases the utility gain from work. In the diagram, the quasi-labor supply shifts outwards. In the new
steady-state, employment is higher. Labor market tightness is unchanged because the labor demand is flat. In the model with constant returns to scale, labor demand is perfectly elastic, so $\epsilon^d = +\infty$. Thus, the multiplier in (27) simplifies to

$$M = -\frac{\partial L^s}{\partial \tau}.$$  \hspace{1cm} (43)

The multiplier is still higher when $A$ is high because $-\partial L^s/\partial \tau > 0$ is increasing in $A$.

Pissarides (2000).—In the standard search-and-matching model of Pissarides (2000), firms produce with constant returns to scale ($\alpha = 1$) and the wage is flexible. When a worker and firm are matched, they bargain over the wage. The workers bargaining power is $\chi \in (0,1)$. The surplus from each match is shared. The worker keeps a fraction $\chi$ of the surplus. The worker’s surplus from a match is the utility gain from work $\Delta U$. The firm’s surplus is the amount of produced goods by a worker $A$ minus the real wage $w$. Worker and firm split the total surplus. Thus, the wage satisfies

$$w = A - \frac{1 - \chi}{\chi} \cdot \Delta U.$$  \hspace{1cm} (44)

Figure 11 Panel (c) shows the effect of a tax cut in bad times and Figure 11 Panel (d) shows the effect of a tax cut in good times. Following an increase in $A$, the labor demand shifts upwards. In the flexible wage model, $A$ raises the wage, which leads to an increase in the utility gain from work. Thus, the quasi-labor supply shifts outwards. In the high $A$ steady-state, employment and labor market tightness are higher. A tax cut increases the utility gain from work. In the diagram, the quasi-labor supply shifts outwards. With a flexible wage, an increase in $\Delta U$ reduces the wage. Therefore, the labor demand shifts upwards. I derive the multiplier of the model in Appendix F. It equals

$$M = -\frac{\partial L}{\partial \tau} = -\frac{\partial L^s}{\partial \tau} + (1 - \chi) \cdot \epsilon^s \cdot \frac{L}{w},$$  \hspace{1cm} (45)

The proof in Appendix F shows that $-\partial L^s/\partial \tau > 0$ is increasing in $A$. $\epsilon^s$ and $L/w$ are decreasing in $A$. Thus, whether $M$ increases when $A$ is high is ambiguous. In the diagram, a tax cut shifts both the labor demand and the quasi-labor supply. Importantly, the quasi-labor supply is convex. Thus, the effect of a shift in the labor demand on employment is higher when $A$ is low. The effect of a shift in the quasi-labor supply is higher when $A$ is high. Which effect dominates depends on the parameters. An extreme case arises when workers have full bargaining power ($\chi = 1$). Then, $w = A$ at all times. The multiplier is $M = -\partial L^s/\tau$ and does not depend on $A$.

I now discuss additional evidence to contrast the alternative models. The evidence on the effects of unemployment insurance (UI) on employment supports the assumptions of the model I propose. A reduction in UI is comparable to a tax cut because it increases the utility gain from work. Landais et al. (2016a) summarize the evidence. They define two elasticities. The microelasticity $\epsilon^m = (\partial L^s/\partial \Delta U) \cdot (\Delta U/L^s)$ $|_0$ measures the percentage increase in labor supply when the utility gain from work increases by 1 percent, given the level of labor market tightness. The macroelasticity $\epsilon^M = (dL/d\Delta U) \cdot (\Delta U/L)$ measures the percentage increase in employment when the utility gain from work increases by 1 percent after labor demand has adjusted. Therefore, the macroelasticity accounts for both the change in jobseekers’ search effort.
and the equilibrium adjustment of tightness. Landais et al. (2016a) conclude that estimates of
the microelasticity are larger than estimates of the macroelasticity. Thus, the empirical evidence
supports $\epsilon^M < \epsilon^m$. In addition, the ratio $\epsilon^M/\epsilon^m$ is higher in good times. I use the multiplier
$M$ to obtain an expression for the macroelasticity. I replace a tax cut $-d\tau$ with an increase in
the utility gain from work $d\Delta U$ and multiply by $\Delta U/L$. Figure 12 represents the elasticities in
the competing models diagrammatically.

For my model with a rigid wage and diminishing marginal returns to labor, I derive the
macroelasticity from the multiplier (26). I obtain $\epsilon^M = \frac{\epsilon^m}{1+\left(\epsilon^s/\epsilon^d\right)}$. Because $\epsilon^s$ and $\epsilon^d$ are both
finite, we have that $\epsilon^M < \epsilon^m$. Moreover, the ratio $\epsilon^M/\epsilon^m$ is larger in good times, because
the quasi-labor supply is convex. Thus, the model is consistent with the empirical evidence of
Landais et al. (2016a). Figure 12 Panel (a) represents the microelasticity and the macroelasticity
of my model in a diagram. The model predicts that an increase in job-search effort lowers labor
market tightness. This is in with the micro evidence of Crépon et al. (2013) discussed above.
In the diagram, we see that an increase in job-search effort lowers tightness because the labor
demand is downward-sloping.

Hall (2005).—From the multiplier in (43), I obtain the macroelasticity $\epsilon^M = \epsilon^m$. In the
model with a fixed wage and diminishing marginal returns to labor, the microelasticity is equal
to the macroelasticity. This is at odds with the empirical evidence of Landais et al. (2016a).
Figure 12 Panel (b) represents the microelasticity and the macroelasticity of the model in a
diagram. The model predicts that an increase in job-search effort has no effect on labor market
tightness. This is at odds with the evidence of Crépon et al. (2013). In the diagram, we see
that an increase in job-search effort has no effect on tightness because the labor demand is a
horizontal line.

Pissarides (2000).—From the multiplier in (45), I obtain the macroelasticity $\epsilon^M = \epsilon^m + (1-\chi) \cdot \epsilon^s \cdot (\Delta U/w)$. The macroelasticity is larger than the microelasticity. Therefore, the model
with a flexible wage and constant returns to labor is inconsistent with the evidence of Landais
et al. (2016a). Figure 12 Panel (c) represents the microelasticity and the macroelasticity of
the model in a diagram. The model predicts that an increase in job-search effort leads to an
increase in labor market tightness. In the diagram, we see that this is the case because the wage
falls and the labor demand shifts upwards. This is at odds with the evidence of Crépon et al.
(2013).

These results highlight that both diminishing marginal returns to labor and a rigid wage
are crucial for the model’s ability to account for the empirical evidence.

5 Concluding Remarks

This paper has presented empirical evidence that the effects of U.S. tax changes on output
depend strongly on the amount of slack in the economy. Tax cuts have large effects on output
only in good times. In bad times, however, the effects on output are small. The finding
questions whether estimates of the average effects of tax shocks from a linear model can provide
meaningful guidance for fiscal policy.

To explain the result, I have proposed a simple search model of unemployment in which the
effect of an income tax cut is low when unemployment is high. I have focussed on a simple version of the model to keep the analysis transparent. Quantitative DSGE models of distortionary taxation are much larger and include features such as habit formation, investment adjustment costs, durable goods and variable capacity utilization.\footnote{See for example Baxter and King (1993), Burnside et al. (2004) and Mertens and Ravn (2011).} An interesting path for future research is to embed the search-and-matching structure of the labor market into a quantitative DSGE model. Specifically, it would be interesting to see whether such a model can adequately match the state-dependent empirical impulse responses to tax shocks.

Another interesting path is to consider other types of tax and government spending policies in the search model of unemployment. The model can also be used to study interdependent effects of fiscal policies.
References


Table 1: Variable Description

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output ($Y$)</td>
<td>Nominal GDP divided by its implicit price deflator</td>
<td>FRED</td>
</tr>
<tr>
<td>Government spending ($G$)</td>
<td>Federal government consumption expenditures and gross investment divided by the GDP deflator.</td>
<td>FRED</td>
</tr>
<tr>
<td>Average tax rate ($ATR$)</td>
<td>Nominal federal tax revenues minus transfers divided by nominal GDP.</td>
<td>FRED</td>
</tr>
<tr>
<td>Narrative tax measure ($RR$)</td>
<td>Narrative measure of exogenous tax changes.</td>
<td>Romer and Romer (2010)</td>
</tr>
<tr>
<td>Average personal income tax rate ($APITR$)</td>
<td>Federal personal income tax revenues including contributions to government social insurance divided by personal income tax base.</td>
<td>Mertens and Ravn (2013)</td>
</tr>
<tr>
<td>Average corporate income tax rate ($ACITR$)</td>
<td>Federal corporate income tax revenues divided by corporate income tax base.</td>
<td>Mertens and Ravn (2013)</td>
</tr>
<tr>
<td>Narrative personal income tax measure ($RR^p$)</td>
<td>Narrative measure of exogenous personal income tax changes.</td>
<td>Mertens and Ravn (2013)</td>
</tr>
<tr>
<td>Narrative corporate income tax measure ($RR^c$)</td>
<td>Narrative measure of exogenous corporate income tax changes.</td>
<td>Mertens and Ravn (2013)</td>
</tr>
<tr>
<td>Tax revenues ($T$)</td>
<td>Nominal federal tax revenues minus transfers divided by the GDP deflator.</td>
<td>FRED</td>
</tr>
<tr>
<td>Consumption ($C$)</td>
<td>Consumers nominal expenditure divided by its deflator.</td>
<td>FRED</td>
</tr>
<tr>
<td>Investment ($I$)</td>
<td>Private sector gross investment divided by its deflator.</td>
<td>FRED</td>
</tr>
<tr>
<td>Hours ($L$)</td>
<td>Product of hours per worker and civilian non-farm employment divided by population. Combined with Francis and Ramey (2002) hours worked series.</td>
<td>Mertens and Ravn (2012)</td>
</tr>
<tr>
<td>Wage ($W$)</td>
<td>Average hourly earning of private employees.</td>
<td>FRED</td>
</tr>
<tr>
<td>Unemployment rate ($U$)</td>
<td>Civilian unemployment rate.</td>
<td>FRED</td>
</tr>
<tr>
<td>Public Debt</td>
<td>Federal government debt held by the public divided by the GDP deflator.</td>
<td>Favero and Giavazzi (2012)</td>
</tr>
<tr>
<td>Nonborrowed reserves</td>
<td>Nonborrowed reserves.</td>
<td>FRED</td>
</tr>
<tr>
<td>Federal funds rate</td>
<td>Effective federal funds rate.</td>
<td>FRED</td>
</tr>
<tr>
<td>Price level ($CPI$)</td>
<td>Consumer price index for all urban consumers.</td>
<td>FRED</td>
</tr>
<tr>
<td>Implicit tax rate</td>
<td>Expected future tax rate implied by tax exempt municipal bond yields and perfect arbitrage. Based on bonds with maturity of one year.</td>
<td>Leeper et al. (2011)</td>
</tr>
<tr>
<td>Defense news</td>
<td>Professional forecasters’ projections of the path of future military spending</td>
<td>Ramey (2011)</td>
</tr>
</tbody>
</table>
Table 2: Peak effect of a tax shock on output (in percent)

<table>
<thead>
<tr>
<th></th>
<th>Romer &amp; Romer Narrative Approach</th>
<th>Blanchard &amp; Perotti Structural VAR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Local Projections-IV</td>
<td>(2)</td>
</tr>
<tr>
<td>Linear Model</td>
<td>-2.03***</td>
<td>-1.61**</td>
</tr>
<tr>
<td>( \min(\hat{\theta}_h) )</td>
<td>(0.68)</td>
<td>(0.62)</td>
</tr>
<tr>
<td>Bad Times</td>
<td>-0.52</td>
<td>-0.47</td>
</tr>
<tr>
<td>( \min(\hat{\theta}_B) )</td>
<td>(1.34)</td>
<td>(0.75)</td>
</tr>
<tr>
<td>Good Times</td>
<td>-3.54***</td>
<td>-2.68***</td>
</tr>
<tr>
<td>( \min(\hat{\theta}_G) )</td>
<td>(1.00)</td>
<td>(0.73)</td>
</tr>
<tr>
<td>Difference</td>
<td>3.02**</td>
<td>2.21*</td>
</tr>
<tr>
<td>( \min(\hat{\theta}_B) - \min(\hat{\theta}_G) )</td>
<td>(1.54)</td>
<td>(1.19)</td>
</tr>
</tbody>
</table>


Table 3: Peak effect of a tax shock on output (in percent): alternative state variables

<table>
<thead>
<tr>
<th></th>
<th>U 6.5%</th>
<th>U HP ( \lambda = 10^3 )</th>
<th>U HP ( \lambda = 10^5 )</th>
<th>U HP ( \lambda = 10^7 )</th>
<th>NBER Dates</th>
<th>Smooth Trans.</th>
<th>U Cont.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
<td>(7)</td>
</tr>
<tr>
<td>Linear Model</td>
<td>-2.03***</td>
<td>-2.03***</td>
<td>-2.03***</td>
<td>-2.03***</td>
<td>-2.03***</td>
<td>-2.03***</td>
<td></td>
</tr>
<tr>
<td>( \min(\hat{\theta}_h) )</td>
<td>(0.68)</td>
<td>(0.68)</td>
<td>(0.68)</td>
<td>(0.68)</td>
<td>(0.68)</td>
<td>(0.68)</td>
<td></td>
</tr>
<tr>
<td>Bad Times</td>
<td>-0.52</td>
<td>-0.78</td>
<td>-0.90</td>
<td>-1.31**</td>
<td>0.25</td>
<td>-1.34*</td>
<td>-0.71</td>
</tr>
<tr>
<td>( \min(\hat{\theta}_B) )</td>
<td>(1.34)</td>
<td>(0.75)</td>
<td>(0.78)</td>
<td>(0.64)</td>
<td>(0.84)</td>
<td>(0.79)</td>
<td>(1.43)</td>
</tr>
<tr>
<td>Good Times</td>
<td>-3.54***</td>
<td>-4.37***</td>
<td>-3.46**</td>
<td>-4.84***</td>
<td>-3.40***</td>
<td>-3.96***</td>
<td>-3.75***</td>
</tr>
<tr>
<td>( \min(\hat{\theta}_G) )</td>
<td>(1.00)</td>
<td>(1.35)</td>
<td>(1.35)</td>
<td>(1.09)</td>
<td>(0.90)</td>
<td>(1.31)</td>
<td>(1.12)</td>
</tr>
<tr>
<td>Difference</td>
<td>3.02**</td>
<td>3.59**</td>
<td>2.55</td>
<td>3.53**</td>
<td>3.65**</td>
<td>2.62*</td>
<td>3.04**</td>
</tr>
<tr>
<td>( \min(\hat{\theta}_B) - \min(\hat{\theta}_G) )</td>
<td>(1.54)</td>
<td>(1.55)</td>
<td>(1.75)</td>
<td>(1.26)</td>
<td>(1.23)</td>
<td>(1.53)</td>
<td>(1.55)</td>
</tr>
</tbody>
</table>

Peak effects of a tax shock on real GDP (in percent). Standard errors in parentheses. *, **, *** indicates statistical significance at the 10%, 5% and 1% level, respectively. (1) uses the baseline state variable. The discrete threshold that separates bad and good times is an unemployment rate of 6.5%. (2) The threshold is the HP-filtered trend unemployment rate using a smoothing parameter of \( \lambda = 10^3 \). (3) The threshold is the HP-filtered trend unemployment rate using \( \lambda = 10^5 \). (4) The threshold is the HP-filtered trend unemployment rate using \( \lambda = 10^7 \). (5) Bad times are NBER recession periods. (6) The state variable is the smooth transition function of past output growth. Estimates in column (1) to (6) are from the local projections-IV in Equation 3. (7) The state variable is the continuous unemployment rate. Estimates from the local projections-IV in Equation B.1. Estimation using quarterly data from 1947Q1 to 2007Q4.
Table 4: Peak effect of a tax shock on output (in percent): additional control variables

<table>
<thead>
<tr>
<th>Baseline</th>
<th>Control for Public Debt</th>
<th>Control for Mon. Policy</th>
<th>Control for Foresight</th>
<th>Vars in Growth Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td>Linear Model</td>
<td>-2.03***</td>
<td>-2.52**</td>
<td>-2.07**</td>
<td>-2.51***</td>
</tr>
<tr>
<td>min($\hat{\theta}_h$)</td>
<td>(0.68)</td>
<td>(1.02)</td>
<td>(0.60)</td>
<td>(0.64)</td>
</tr>
<tr>
<td>Bad Times</td>
<td>-0.52</td>
<td>-0.74</td>
<td>-0.64</td>
<td>-0.68</td>
</tr>
<tr>
<td>min($\hat{\theta}_B$)</td>
<td>(1.34)</td>
<td>(1.29)</td>
<td>(0.64)</td>
<td>(1.09)</td>
</tr>
<tr>
<td>Good Times</td>
<td>-3.54***</td>
<td>-3.67***</td>
<td>-3.05***</td>
<td>-3.59***</td>
</tr>
<tr>
<td>min($\hat{\theta}_G$)</td>
<td>(1.00)</td>
<td>(1.12)</td>
<td>(0.99)</td>
<td>(0.96)</td>
</tr>
<tr>
<td>Difference</td>
<td>3.02**</td>
<td>2.93*</td>
<td>2.41**</td>
<td>2.91**</td>
</tr>
<tr>
<td>min($\hat{\theta}_B$) - min($\hat{\theta}_G$)</td>
<td>(1.54)</td>
<td>(1.71)</td>
<td>(1.72)</td>
<td>(1.45)</td>
</tr>
</tbody>
</table>

Peak effects of a tax shock on real GDP (in percent). Standard errors in parentheses. *, **, *** indicates statistical significance at the 10%, 5% and 1% level, respectively. (1) uses the baseline set of controls. (2) uses four lags of log real federal government debt as additional controls. (3) uses four lags of the federal funds rate, the log CPI price level and log-non-borrowed reserves as additional controls. (4) uses contemporaneous values and four lags of the implicit tax rate, defense stock returns and defense stock news as additional controls. (5) uses the baseline specification but with variables expressed in annual growth rates instead of log levels. Estimates from the local projections-IV in Equation 3. Estimation using quarterly data from 1947Q1 to 2007Q4.

Table 5: Peak effect of a tax shock on output (in percent): alternative methods

<table>
<thead>
<tr>
<th>Baseline</th>
<th>Proxy SVAR</th>
<th>Augmented VAR</th>
<th>Truncated MA</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(5)</td>
</tr>
<tr>
<td>Linear Model</td>
<td>-2.03***</td>
<td>-1.22**</td>
<td>-1.61**</td>
</tr>
<tr>
<td>min($\hat{\theta}_h$)</td>
<td>(0.68)</td>
<td>(0.60)</td>
<td>(0.67)</td>
</tr>
<tr>
<td>Bad Times</td>
<td>-0.52</td>
<td>-0.34</td>
<td>-0.75</td>
</tr>
<tr>
<td>min($\hat{\theta}_B$)</td>
<td>(1.34)</td>
<td>(0.82)</td>
<td>(0.87)</td>
</tr>
<tr>
<td>Good Times</td>
<td>-3.54***</td>
<td>-2.52***</td>
<td>-2.70***</td>
</tr>
<tr>
<td>min($\hat{\theta}_G$)</td>
<td>(1.00)</td>
<td>(0.73)</td>
<td>(0.72)</td>
</tr>
<tr>
<td>Difference</td>
<td>3.02**</td>
<td>2.18*</td>
<td>1.95*</td>
</tr>
<tr>
<td>min($\hat{\theta}_B$) - min($\hat{\theta}_G$)</td>
<td>(1.54)</td>
<td>(1.10)</td>
<td>(1.13)</td>
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</tbody>
</table>

Table 6: Calibration of the New Keynesian model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Target/Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>steady-state Targets</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$A$</td>
<td>1.00</td>
<td>Steady-state technology</td>
<td>Michaillat (2014)</td>
</tr>
<tr>
<td>$u$</td>
<td>0.064</td>
<td>Steady-state unemployment</td>
<td>Michaillat (2014)</td>
</tr>
<tr>
<td>$\theta$</td>
<td>0.43</td>
<td>Steady-state labor market tightness</td>
<td>Michaillat (2014)</td>
</tr>
<tr>
<td>$s$</td>
<td>1</td>
<td>Steady-state job-search effort</td>
<td>Michaillat (2014)</td>
</tr>
<tr>
<td><strong>Parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\eta$</td>
<td>0.7</td>
<td>Elasticity of matching to unemployment</td>
<td>Michaillat (2014)</td>
</tr>
<tr>
<td>$r$</td>
<td>0.21</td>
<td>Recruiting cost</td>
<td>Michaillat (2014)</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>0.01</td>
<td>Job-destruction rate</td>
<td>Michaillat (2014)</td>
</tr>
<tr>
<td>$\nu$</td>
<td>0.5</td>
<td>Elasticity of real wage to technology</td>
<td>Michaillat (2014)</td>
</tr>
<tr>
<td>$\phi_{\pi}$</td>
<td>1.5</td>
<td>Elasticity of monetary rule to inflation</td>
<td>Michaillat (2014)</td>
</tr>
<tr>
<td>$\rho_{\tau}$</td>
<td>0.96</td>
<td>Elasticity of monetary rule to lagged interest rate</td>
<td>Michaillat (2014)</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>61</td>
<td>Price adjustment cost</td>
<td>Michaillat (2014)</td>
</tr>
<tr>
<td>$\rho_A$</td>
<td>0.992</td>
<td>Autocorrelation of technology</td>
<td>Michaillat (2014)</td>
</tr>
<tr>
<td>$\rho_{\tau}$</td>
<td>0.992</td>
<td>Autocorrelation of taxes</td>
<td>Matches empirical impulse response function of the average tax rate to a tax shock</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.66</td>
<td>Marginal returns to labor</td>
<td>Michaillat (2014)</td>
</tr>
<tr>
<td>$\beta$</td>
<td>0.999</td>
<td>Discount factor</td>
<td>Michaillat (2014)</td>
</tr>
<tr>
<td>$\epsilon$</td>
<td>11</td>
<td>Elasticity of substitution across goods</td>
<td>Michaillat (2014)</td>
</tr>
<tr>
<td>$m$</td>
<td>0.17</td>
<td>Matching effectiveness</td>
<td>Matches steady-state targets (Michaillat, 2014)</td>
</tr>
<tr>
<td>$\omega$</td>
<td>0.64</td>
<td>Real wage level</td>
<td>Matches steady-state targets (Michaillat, 2014)</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>0.22</td>
<td>Disutility from job search: convexity</td>
<td>Landais et al. (2016a)</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.33</td>
<td>Disutility from job search: level</td>
<td>Matches steady-state targets (Landais et al., 2016a)</td>
</tr>
<tr>
<td>$\tau$</td>
<td>0.26</td>
<td>steady-state labor income tax rate</td>
<td>Matches estimate of the average effective labor income tax rate by Mendoza et al. (1994)</td>
</tr>
</tbody>
</table>
Figure 1: Romer & Romer (2010) narrative measure of exogenous tax changes

Figure 2: Romer & Romer (2010) narrative measure and the unemployment rate
Figure 3: Impulse responses of real GDP ($Y$), real federal government spending ($G$) and the average tax rate ($ATR$) to a tax shock. Estimates from the linear local projections-IV in Equation 1 using quarterly data from 1947Q1 to 2007Q4. Shaded areas are 90% confidence bands using Newey-West standard errors.
Figure 4: Impulse responses of real GDP ($Y$), real federal government spending ($G$) and the average tax rate ($ATR$) to a tax shock. Estimates from the linear local projections-IV in Equation 1 (dashed line) or from the state-dependent local projections-IV in Equation 3 (plain line). Shaded areas are 90% confidence bands using Newey-West standard errors. Estimation using quarterly data from 1947Q1 to 2007Q4.
Figure 5: Impulse responses of real federal tax revenues ($T$), real federal government spending ($G$) and real GDP ($Y$) to a tax shock. Estimates from a linear VAR (dashed line) or from the state-dependent VAR in Equation 4 (plain line). Shaded areas are 90% confidence bands calculated with a recursive wild bootstrap using 10,000 replications. Estimation using quarterly data from 1947Q1 to 2007Q4.
Figure 6: Impulse responses of real consumption expenditures ($C$), real private investment ($I$), hours worked ($L$), average hourly earnings ($W$) to a tax shock. Estimates from the linear local projections-IV in Equation 1 (dashed line) or from the state-dependent local projections-IV in Equation 3 (plain line). Shaded areas are 90% confidence bands using Newey-West standard errors. Estimation using quarterly data from 1947Q1 to 2007Q4.
Figure 7: Mertens and Ravn (2013) narrative measures of exogenous personal income tax changes (top panel) and exogenous corporate income tax changes (bottom panel). Exogenous tax changes are expressed in percent of GDP.
Figure 8: Impulse responses of real GDP ($Y$) to a personal income tax shock (top panels). Impulse responses of real GDP ($Y$) to a corporate income tax shock (bottom panels). Estimates from a linear VAR-LP (dashed line) or from the state-dependent VAR-LP in Equation 14 (plain line). Shaded areas cover 90% of the posterior probability. Estimation using quarterly data from 1950Q1 to 2006Q4.
Employment Labor market tightness

(a) Bad times: steady-state with a low $A$

(b) Good times: steady-state with a high $A$

(c) Effect of an income tax cut in bad times

(d) Effect of an income tax cut in good times

Figure 9: Steady-state equilibria in the search-and-matching model
Figure 10: Peak effects of a 1 percentage point reduction of the labor income tax rate on log output ($Y$), labor market tightness ($\theta$) and the unemployment rate ($u$). Results from simulations of the calibrated New Keynesian model with search-and-matching frictions in Section 4.2. The peak effect is the extremum effect of a tax cut in response to 1 of 16 technology shocks ranging from -3.6 percent to +5.4 percent. The unemployment rate on the x-axis is the extremum of the unemployment rate after the technology shock, without a tax cut.
Figure 11: Steady-state equilibria in the Hall (2005) model and the Pissarides (2000) model
Employment market tightness
*+
*,
*+
Δ. ↑
*

(a) Model with fixed wage and diminishing returns

(b) Hall (2005) model

(c) Pissarides (2000) model

Figure 12: Microelasticity and macroelasticity in the competing models
A Estimating State-Dependent Impulse Responses: VAR vs. Local Projections

I show that calculating state-dependent impulse responses from a VAR instead of LPs requires an additional assumption about how the shock affects the state variable.

State-Dependent VAR.—Consider the state-dependent VAR(1):\footnote{For simplicity of exposition, I assume a VAR(1) representation. It is straightforward to generalize the results to a VAR(p) and writing it in companion form.}

$$X_t = I_t \left[ A^B X_{t-1} + C^B \epsilon_t \right] + (1 - I_t) \left[ A^G X_{t-1} + C^G \epsilon_t \right] + u_t.$$ \hspace{1cm} (1)

$X_t$ is a vector of endogenous variables. $I_t$ is the state variable. $\epsilon_t$ is a structural shock. The superscript $B$ denotes the bad state and $G$ the good state. I denote the impulse response of $X$ to a unit shock to $\epsilon_t$ at horizon $h \in \{0, H\}$ by $\beta^j_h$, where $j = \{B, G\}$. Then, the impulse response to a unit shock at horizon $h = 0$ is given by $\beta^B_0 = C^B$ if the shock hits in bad times, and, by $\beta^G_0 = C^G$ if the shock hits in good times. To calculate the impulse responses at $h = 1$, I am iterating forward the VAR by one period

$$X_{t+1} = I_{t+1} \left[ A^B X_t + C^B \epsilon_{t+1} \right] + (1 - I_{t+1}) \left[ A^G X_t + C^G \epsilon_{t+1} \right] + u_{t+1}.$$ \hspace{1cm} (2)

I plug in $X_t$ from above to get

$$X_{t+1} = I_{t+1} \left[ A^B \left( I_t \left[ A^B X_{t-1} + C^B \epsilon_t \right] + (1 - I_t) \left[ A^G X_{t-1} + C^G \epsilon_t \right] + u_t \right) + C^B \epsilon_{t+1} \right]$$
$$+ \left( (1 - I_{t+1}) \left[ A^G \left( I_t \left[ A^B X_{t-1} + C^B \epsilon_t \right] + (1 - I_t) \left[ A^G X_{t-1} + C^G \epsilon_t \right] + u_t \right) + C^G \epsilon_{t+1} \right) + u_{t+1}. \right.$$ \hspace{1cm} (3)

Note that it is impossible to pin down the response of $X_{t+1}$ to $\epsilon_t$ without making an assumption about how the shock affects the state of the economy in $t + 1$. The standard assumption is that the structural shock does not alter the state of the economy over the impulse response horizon.\footnote{See for instance Auerbach and Gorodnichenko (2012b) and Ramey and Zubairy (2016).}

This implies $I_t = I_{t+1} + I_{t+2} + ... + I_{t+H}$. Using this assumption, the impulse response to a unit shock at horizon $h = 1$ is given by $\beta^B_1 = A^B C^B$ if the shock hits in bad times, and, by $\beta^G_1 = A^G C^G$ if the shock hits in good times.

State-Dependent Local Projections.—To allow for an easy comparison between methods, I assume that we use the same data as for the VAR, that we want to generate impulse responses for all variables in $X_t$, and that we use a lag of $X_t$ as control:

$$X_{t+h} = I_t \left[ \gamma^B X_{t-1} + \beta^B_h \epsilon_t \right] + (1 - I_t) \left[ \gamma^G X_{t-1} + \beta^G_h \epsilon_t \right] + u_{t+h},$$ \hspace{1cm} (4)

The impulse response at $h = 0$ is estimated from

$$X_t = I_t \left[ \gamma^B X_{t-1} + \beta^B_h \epsilon_t \right] + (1 - I_t) \left[ \gamma^G X_{t-1} + \beta^G_h \epsilon_t \right] + u_t,$$ \hspace{1cm} (5)

A comparison with the state-dependent VAR representation reveals that the estimated impulse
responses are identical at horizon \( h = 0 \). The impulse response at \( h = 1 \) is estimated from

\[
X_{t+1} = I_t \left[ \gamma^B X_{t-1} + \beta^B_h \epsilon_t \right] + (1 - I_t) \left[ \gamma^G X_{t-1} + \beta^G_h \epsilon_t \right] + u_t,
\]

Note that, other than in the state-dependent VAR, the impulse response at horizon \( h = 1 \) does not depend on the state-variable at time \( t + 1 \). Hence, no additional assumption is required.

**B Sensitivity Analysis**

This section performs a sensitivity analysis. In B.1, I explore alternative state variables. In B.2, I study whether the results are robust to using additional controls. In B.3, I use an alternative trend assumption. In B.4, I study robustness to alternative econometric methods. In B.5, I examine whether tax shocks have sign-dependent effects.

**B.1 State Variable**

I investigate whether the findings are robust to using alternative state variables. This robustness check is important because alternative measures change the distribution of tax shocks over the states of the economy. Table B.1 summarizes the distribution of tax shocks for the state variables I consider.

**Alternative Thresholds.**—First I keep the focus on the unemployment rate with a discrete threshold that separates the good state from the bad. I now allow for a time-varying threshold and consider deviations from the Hodrick-Prescott filtered unemployment rate. I use three alternative smoothing parameters: \( \lambda = 10^3 \), \( \lambda = 10^5 \) and \( \lambda = 10^7 \). Table 3 summarizes the peak effect of a tax shock on real GDP in good times \( \min(\hat{\theta}_G^h) \), and bad times \( \min(\hat{\theta}_B^h) \), and reports the test statistic for the null hypothesis \( \min(\hat{\theta}_G^h) - \min(\hat{\theta}_B^h) = 0 \) for the alternative thresholds. In three out of four cases, the difference in peak effects is significant at the 5% level. For \( \lambda = 10^5 \) the difference falls marginally short of significance at the 10% level.

**Continuous State Variable.**—I now use the continuous unemployment rate as a state variable. To implement this change, I adapt (3):

\[
x_{t+h} = a_h + \beta_1^h ATR_t + \beta_2^h U_{t-1} \times ATR_t + \gamma_1^h z_t + \gamma_2^h U_{t-1} \times z_t + \delta^D_t + \kappa U_{t-1} + u_{t+h}. \tag{B.1}
\]

I use \( RR_t \) as an instrument for \( \epsilon_t^r \), and \( U_{t-1} \times RR_t \) as an instrument for \( U_{t-1} \times \epsilon_t^r \). I assume that the economy is in a bad state if the unemployment rate is one standard error (\( \sigma_U \)) above its median (\( \tilde{U} \)), and in a good state if the unemployment rate is one standard error below its median. The benchmark impulse response at horizon \( h \) is now given by \( \theta_h = \left( \beta_1^h + \beta_2^h \times \tilde{U} \right) \sigma_t \).

The impulse response in the good state is given by \( \theta_G^h = \left( \beta_1^h + \beta_2^h \times (\tilde{U} - \sigma_U) \right) \sigma_t \) and in the bad state by \( \theta_B^h = \left( \beta_1^h + \beta_2^h \times (\tilde{U} + \sigma_U) \right) \sigma_t \). Table 3 reports that the estimated peak effects are remarkably close to the baseline specification. The difference in peak effects \( \min(\theta_G^h) - \min(\theta_B^h) = 2.6 \) percentage points and significant at the 5% level.

**State of the Business Cycle.**—Until now I used measures of economic slack as the state variable. However, the effect of tax shocks might also depend on the state of the business
cycle. Note that the two concepts have important differences. Measures of the state of the business cycle indicate periods in which the economy is moving from its peak to its trough. A typical recession encompasses periods in which unemployment is rising from its low point to its high point. Therefore periods that are marked as recessions are not necessarily periods of high economic slack. Only about half of the quarters that are official recessions are also periods of high unemployment. I consider two business cycle indicators: NBER recession dates and Auerbach and Gorodnichenko’s (2012b) smooth transition function of output growth. To use the NBER recession dates as a state variable I simply set \( I_t = NBER_t \). To implement the approach of Auerbach and Gorodnichenko (2012b) I set

\[
I_t = F(s_t) = \frac{\exp(-\nu s_t)}{1 + \exp(-\nu s_t)}.
\]

\( s_t \) is the standardized seven-quarter moving average of output growth. I follow Auerbach and Gorodnichenko (2012b) and set \( \nu = 1.5 \) which implies that the economy spends about 20% of time in recession. Other than Auerbach and Gorodnichenko (2012b) I use a lagged moving average instead of a centered one. Table 3 reports that the difference in peak effects is 3.6 percentage points and significant at the 5% level when using NBER recession dates, and 2.6 percentage points and significant at the 10% level when using the smooth transition function of output growth. I conclude from this section that the main results are robust to using alternative state variables. For a quick comparison, Figure B.1 plots the point estimates of the state-dependent LP-IV using the alternative state variables.

### B.2 Controls

I investigate whether the results are robust to introducing additional controls. First, I add four lags of log of real federal government debt to the public to the set of controls. Government debt is a potentially important variable since any change in taxes must eventually lead to adjustments in fiscal instruments, see Leeper (2010) and Favero and Giavazzi (2012).

Second, I aim to control for monetary policy and add four lags of variables used in standard monetary VARs to the set of controls. These are the federal funds rate, the log CPI price level, and log non-borrowed reserves.

Third, I address the possibility of fiscal foresight. To address this issue, I follow Mertens and Ravn (2014) and make use of three variables. These are (i) the implicit tax rate, a measure of expected future taxes that is implied by tax exempt municipal bond yields and perfect arbitrage, constructed by Leeper et al. (2011); (ii) defense stock returns, a series for the accumulated excess returns of large U.S. military contractors constructed by Fisher and Peters (2010); (iii) defense news, a variable which contains professional forecasters’ projections of the path of future military spending, constructed by Ramey (2011). I use the contemporaneous values and four lags of the three variables as controls.\(^{50}\)

Figure B.2 presents the point estimates of the LP-IVs using additional controls. Expanding the set of controls has little effect on the estimated coefficients. Table 4 reports the peak effects

\(^{50}\)I use the implicit tax rate variable based on bonds with maturity of one year. Since this data is only available since 1953Q2, the same was shortened correspondingly in this case.
in good times and bad for the specifications using additional controls variables. The difference between peak effects is significant at the 5% level using controls for monetary policy and fiscal foresight, and significant at the 10% level using controls for public debt.

B.3 Trend Assumption

In the baseline specification, I use variables in log levels and allow for a quadratic deterministic trend. Instead, I now switch to a stochastic trend assumption and express output and government spending in annual growth rates. Table 4 reports that the difference in peak effects for the growth specification is 2.5 percentage points and significant at the 5% level.

B.4 Econometric Methods

I investigate whether the results are robust to using alternative methodologies that have been proposed in the literature. I discuss results for three alternatives. These are (i) the *Proxy SVAR* proposed by Mertens and Ravn (2014), (ii) the *Augmented VAR* 51, (iii) the *Truncated MA* proposed by Romer and Romer (2010).

*Proxy SVAR.*—Mertens and Ravn (2014, henceforth MR) propose to use the RR narrative measure as an external instrument for the latent tax shock in a standard fiscal VAR. The specification is identical to MR, but additionally allows for state-dependent effects of tax shocks:

\[
X_t = \begin{bmatrix} T_t, G_t, Y_t \end{bmatrix}'X_{t-1} = \begin{bmatrix} X_{t-1}'^T, \ldots, X_{t-4}'^T \end{bmatrix}. D_t \text{ contains a quadratic deterministic trend and a dummy for 1975Q2.} \epsilon_t \text{ is a vector of structural shocks with } E(\epsilon_t) = 0, E(\epsilon_t \epsilon_t') = I \text{ and } E(\epsilon_t \epsilon_s') = 0 \text{ for } s \neq t. \ u_t = [u_t^T, u_t^G, u_t^Y]' \text{ are the reduced form residuals with } u_t \sim N(0, \Sigma_t). \ \Sigma_t \text{ is a vector of state variables.} \]

\[
\begin{align*}
X_t &= I_{t-1} A^B X_{t-1} + (1 - I_{t-1}) A^G X_{t-1} + \delta D_t + u_t \\
\epsilon_t &= I_{t-1} C^B \epsilon_t + (1 - I_{t-1}) C^G \epsilon_t \\
\Sigma_t &= I_{t-1} \Sigma^B + (1 - I_{t-1}) \Sigma^G.
\end{align*}
\]

X_t = [T_t, G_t, Y_t]'X_{t-1} = [X_{t-1}', \ldots, X_{t-4}']. D_t \text{ contains a quadratic deterministic trend and a dummy for 1975Q2.} \epsilon_t \text{ is a vector of structural shocks with } E(\epsilon_t) = 0, E(\epsilon_t \epsilon_t') = I \text{ and } E(\epsilon_t \epsilon_s') = 0 \text{ for } s \neq t. \ u_t = [u_t^T, u_t^G, u_t^Y]' \text{ are the reduced form residuals with } u_t \sim N(0, \Sigma_t). \ \Sigma_t \text{ is a vector of state variables.} \]

\[
\begin{align*}
X_t &= I_{t-1} A^B X_{t-1} + (1 - I_{t-1}) A^G X_{t-1} + \delta D_t + u_t \\
\epsilon_t &= I_{t-1} C^B \epsilon_t + (1 - I_{t-1}) C^G \epsilon_t \\
\Sigma_t &= I_{t-1} \Sigma^B + (1 - I_{t-1}) \Sigma^G.
\end{align*}
\]

Since we are only interested in the effects of a tax shock, it is sufficient to identify the parameters in the first column of C^G and C^B. I get consistent estimates of the first column by running a regression of u_t on (1 - I_{t-1}) \times RR_t and (1 - I_{t-1}) \times RR_t. In a state-dependent VAR, one needs to impose additional assumptions on how the shock affects the state variable. I follow the standard approach in the literature and assume that the state is constant over the impulse response horizon.\footnote{\textsuperscript{52} See for example Auerbach and Gorodnichenko (2012b) and Ramey and Zubairy (2016).}

Figure B.3 presents the impulse responses. The dashed lines serve as a benchmark and depict impulse response estimates from a linear version of (B.2). Shaded areas are 90% confidence bands that I compute with a recursive wild bootstrap using 10,000 replications, see Gonçalves and Kilian (2004). Following Mertens and Ravn (2014), the impulse responses are scaled by the narrative measure RR_t serves as an external instrument for the latent tax shock \epsilon_t^T. Hence, I_{t-1} \times RR_t serves as an instrument for (1 - I_{t-1}) \times \epsilon_t^T, and (1 - I_{t-1}) \times RR_t as an instrument for (1 - I_{t-1}) \times \epsilon_t^T. Since we are only interested in the effects of a tax shock, it is sufficient to identify the parameters in the first column of C^G and C^B. I get consistent estimates of the first column by running a regression of u_t on (1 - I_{t-1}) \times RR_t and (1 - I_{t-1}) \times RR_t. In a state-dependent VAR, one needs to impose additional assumptions on how the shock affects the state variable. I follow the standard approach in the literature and assume that the state is constant over the impulse response horizon.\footnote{\textsuperscript{51} Many authors interpret the narrative measure as the tax shock and introduce it as an exogenous regressor in a reduced form VAR. See for example Mertens and Ravn (2011; 2012), Favero and Giavazzi (2012), Perotti (2012).\textsuperscript{52} See for example Auerbach and Gorodnichenko (2012b) and Ramey and Zubairy (2016).}
inverse of the average tax revenue to GDP ratio. The results are similar to those of the baseline specification. Tax shocks have no statistically significant effect on output in bad times. In good times, on the other hand, tax shocks have much stronger effects on output than the linear model suggests. Importantly, the impulse responses for tax revenues and government spending exhibit no state-dependence.\textsuperscript{53}

**Augmented VAR.**—Some authors treat the narrative measure as the tax shock and introduce it as an exogenous regressor in a reduced form VAR. I augment a standard fiscal VAR with the RR narrative measure:

\[ X_t = I_{t-1} \left[ C^B RR_t + A^B X_{t-1} \right] + \left(1 - I_{t-1} \right) \left[ C^G RR_t + A^G X_{t-1} \right] + \delta D_t + u_t. \]  

(B.3)

RR\_t = [RR\_t^1, ..., RR\_t^{t-4}]. I again assume that the state remains constant over the impulse response horizon. Figure B.4 presents the results. I find that the estimates are very close to the ones obtained from the proxy SVAR.

**Truncated MA.**—RR estimate the effects of the narrative measure on output from a truncated moving average representation. Other than RR, I use the log level of output instead of its growth rate to allow for an easy comparison between methods. The state-dependent version of the truncated MA is

\[ Y_t = \alpha + \sum_{h=0}^{12} [I_{t-1-h} \theta^B_h RR_{t-h} + (1 - I_{t-1-h}) \theta^G_h RR_{t-h}] + \delta' D_t + u_t. \]  

(B.4)

The results from the truncated MA model are shown in Figure B.5. The peak effects are larger than in the VAR specifications and are instead very close to the LP-IV estimates.

Table 4 collects the peak effects for the three alternative econometric methods. The peak effects in the VAR specification are a degree of magnitude smaller than in the LP-IV and truncated MA specifications. A possible explanation for this is the tighter dynamic structure VARs impose on the shape of the impulse response function. Nevertheless, the main result is robust to using any of the alternative methods. In all specifications, a tax shock that hits the economy in good times has larger effects on output than the corresponding linear model suggests. A tax shock that hits in bad times has small and statistically insignificant effects.

### B.5 Sign-Dependence

I study whether tax increases have different effects on output than tax reductions.\textsuperscript{54} To that end, I estimate the sign-dependent LPs:

\[ x_{t+h} = a_h + \theta^T_h RR_{t+h}^+ + \theta^-_h RR_{t+h}^- + \gamma^T_h z_t + \delta^T_h D_t + u_{t+h}. \]  

(B.5)

\textsuperscript{53}In the linear model, I find a peak effect on output of -1.2%. This result is close to Figure 5 in MR. In their baseline specification, they use a subset of RR tax changes that removes 18 non-zero observations and find a larger peak effect. Once they use all RR tax changes, their estimates are very close to mine.

\textsuperscript{54}Recent evidence suggests that many macroeconomic shocks have sign-dependent effects. For instance, Barnichon and Matthes (2016) find that contractionary monetary policy is more powerful than its expansionary counterpart. Barnichon and Matthes (2017) find that a reduction in government spending has a stronger effect on economic activity than an increase. Barnichon et al. (2016) show that credit supply contractions have larger effects on output than credit supply expansions.
where $RR_i^+$ are narratively identified exogenous tax increases and $RR_i^-$ tax reductions. I use the same set of deterministic terms and controls as in the baseline specification. The impulse response of $x$ at horizon $h$ to a positive tax shock is given by $\theta_h^+$, and to a negative tax shock by $\theta_h^-$. Figure B.6 presents the results. The plain lines are the point estimates of $\theta_h^+$ and $\theta_h^-$. The shaded areas are 90% confidence bands. The dashed lines are the point estimates from the linear model in (1). For ease of comparison, the impulse responses to a tax reduction are multiplied by -1. I find no evidence that tax shocks have sign-dependent effects on output. The effects of tax increases and reductions appear to be fairly symmetrical as the point estimates of the sign-dependent model are close to the point estimates of the linear model over the entire impulse response horizon.
Table B.1: Distribution of tax shocks using alternative state indicators

<table>
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<th>U 6.5%</th>
<th>U HP λ = 10³</th>
<th>U HP λ = 10⁶</th>
<th>U HP λ = 10⁷</th>
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Summary statistics are for non-zero observations of the tax shocks. (1) is the baseline state variable. The discrete threshold that separates bad and good times is an unemployment rate of 6.5%. (2) The threshold is the HP-filtered trend unemployment rate using a smoothing parameter of $\lambda = 10^3$. (3) The threshold is the HP-filtered trend unemployment rate using $\lambda = 10^6$. (4) The threshold is the HP-filtered trend unemployment rate using $\lambda = 10^7$. (5) Bad times are NBER recession periods. (6) The state variable is the smooth transition function of past output growth. Bad times are periods in which $F(s_t) > 0.8$. (7) The state variable is the continuous unemployment rate. Bad times are periods in which the unemployment rate is below its median.
Figure B.1: Impulse responses of real GDP ($Y$) to a tax shock using alternative state variables. 

**Baseline:** the discrete threshold that separates bad and good times is an unemployment rate of 6.5%. 

*HP* $^{10^3}$: The threshold is the HP-filtered trend unemployment rate using a smoothing parameter of $\lambda = 10^3$. 

*HP* $^{10^5}$: The threshold is the HP-filtered trend unemployment rate using $\lambda = 10^5$. 

*HP* $^{10^7}$: The threshold is the HP-filtered trend unemployment rate using $\lambda = 10^7$. 

*U* continuous: the state variable is the continuous unemployment rate. 

*Smooth Transition:* the state variable is the smooth transition function of past output growth. 

*NBER dates:* bad times are NBER recession periods. Estimates from the local projections-IV in Equation 3 (plain line).

Figure B.2: Impulse responses of real GDP ($Y$) to a tax shock. *Baseline:* uses the baseline set of controls. *+ Public Debt:* uses four lags real federal government debt as additional controls. *+ Monetary Policy:* uses four lags of the federal funds rate, the CPI price level and non-borrowed reserves as additional controls. *+ Fiscal Foresight:* uses contemporaneous values and four lags of the implicit tax rate, defense stock returns and defense stock news as additional controls. Estimates from the linear local projections-IV in Equation 1 (dashed line) or from the state-dependent local projections-IV in Equation 3 (plain line). Shaded areas are 90% confidence bands using Newey-West standard errors. Estimation using quarterly data from 1947Q1 to 2007Q4. *+ Fiscal Foresight:* uses quarterly data from 1953Q2 to 2007Q4.
Figure B.3: Impulse responses of real federal tax revenues ($T$), real federal government spending ($G$) and real GDP ($Y$) to a tax shock. Estimates from a linear proxy SVAR (dashed line) or from the state-dependent proxy SVAR in Equation B.2 (plain line). Shaded areas are 90% confidence bands calculated with a recursive wild bootstrap using 10,000 replications. Estimation using quarterly data from 1947Q1 to 2007Q4.
Figure B.4: Impulse responses of real federal tax revenues ($T$), real federal government spending ($G$) and real GDP ($Y$) to a tax shock. Estimates from a linear augmented VAR (dashed line) or from the state-dependent augmented VAR in Equation B.3 (plain line). Shaded areas are 90% confidence bands calculated with a recursive wild bootstrap using 10.000 replications. Estimation using quarterly data from 1947Q1 to 2007Q4.
Figure B.5: Impulse responses of real GDP (Y) to a tax shock. Estimates from a linear truncated MA (dashed lines) or from the state-dependent truncated MA in Equation B.4 (plain lines). Shaded areas are 90% confidence bands calculated with a recursive wild bootstrap using 10,000 replications. Estimation using quarterly data from 1947Q1 to 2007Q4.

Figure B.6: Impulse responses of real GDP (Y) to a positive tax shock (left panel) and to a negative tax shock (right panel). Estimates from the linear local projections in Equation 1 (dashed line) or from the sign-dependent local projections in B.5 (plain line). Shaded areas are 90% confidence bands using Newey-West standard errors. Estimation using quarterly data from 1947Q1 to 2007Q4. For ease of comparison the responses to a tax reduction are multiplied by -1.
C State-Dependent VAR-LP

I extend the VAR-LP to allow for state-dependent impulse response functions. Assume we have reason to believe that the economy can be approximated by a state-dependent VAR(1):

$$X_t = I_{t-1}A^B X_{t-1} + (1 - I_{t-1})A^G X_{t-1} + u_t$$

The state-dependent local projections are

$$X_{t+h} = I_{t-1} \beta^B_h X_{t-1} + (1 - I_{t-1}) \beta^G_h X_{t-1} + v_{t+h}$$

$$v_{t+h} \sim N(0, \Sigma_{h,t})$$

$$\Sigma_{h,t} = I_{t-1} \Sigma_{h,B} + (1 - I_{t-1}) \Sigma_{h,G}$$.

In a state-dependent VAR, one needs to impose additional assumptions on how the shock affects the state variable. A common assumption is to impose that the shock of interest can not alter the state within the impulse response horizon. Using this assumption the state-dependent impulse response functions of the two approaches are given by

$$VAR - IR^s(h) = A^{h+1}$$

$$LP - IR^s(h) = \beta^s_h$$.

$s = \{B, G\}$ denotes the state of the economy. As in the linear setup, the two approaches are identical at horizon $h = 0$. Again, the coefficients $\beta^s_h$ are centered around the impulse responses implied by the VAR:

$$\beta^s_h \mid \beta^s_0, \lambda_h \sim N((\beta^0)^{h+1}, V_{h,s}), \text{ for } h > 1.$$  

For each horizon $h$ and state $s$, I use a standard Minnesota prior such that

$$V_{h,i,j,s} = \lambda_h^2 \frac{\sigma^2_{h,i,s}}{\sigma^2_{h,j,s}}$$

As discussed above, the larger $\lambda_h$, the closer the impulse response estimates are to the LP-IR. Thus, in a state-dependent model, a higher $\lambda_h$ also relaxes the assumption that the shock does not cause the economy to transition to another state. Following Kadiyala and Karlsson (1997), I set the prior for $\Sigma_{h,j}$ to

$$\Sigma_{h,s} \mid \lambda_h \sim IW(\Phi_{h,s}, n + 2)$$

$$\Phi_{h,s} = diag(\sigma^2_{h,s,1}, \ldots, \sigma^2_{h,s,n}).$$

$\sigma^2_{h,s,i}$ is the Newey-West corrected variance of a univariate local projection of variable $i$ starting in state $s$ on itself at horizon $h$.

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55See for example Auerbach and Gorodnichenko (2012b) and Ramey and Zubairy (2016).
D Proofs

PROOF OF LEMMA 4:
Implicit differentiation of the first equilibrium condition in (24) yields

\[
\frac{d\theta}{dA} = \frac{\partial L_d}{\partial A} \left[ \frac{\partial L_s}{\partial \theta} \frac{-\partial L_d}{\partial \theta} \right]^{-1} \quad (D.1)
\]

The signs of \(\partial L_d/\partial \theta\) and \(\partial L_s/\partial \theta\) are from Lemma 2 and Lemma 3. The sign of \(\partial L_d/\partial A\) comes from the labor demand in (20). Thus, \(d\theta/dA > 0\). The other results follow, because \(L = L_s(\theta, \tau)\) and \(u = 1 - (1 - \lambda)L\).

PROOF OF PROPOSITION 1:
I first proof part (i). Implicit differentiation of the first equilibrium condition in (24) yields

\[
\frac{d\theta}{d\tau} = -\frac{\partial L_s}{\partial \tau} \left[ \frac{\partial L_s}{\partial \theta} \frac{-\partial L_d}{\partial \theta} \right]^{-1} \quad (D.2)
\]

The signs of the derivatives are from Lemma 2 and Lemma 3. Thus, \(d\theta/d\tau > 0\).

Implicit differentiation of the second equilibrium condition in (25) yields

\[
\frac{\partial L}{\partial \tau} = \frac{\partial L_d}{\partial \theta} \cdot \frac{d\theta}{d\tau} \quad (D.3)
\]

Thus, \(\partial L/\partial \tau < 0\). It follows that \(M > 0\), and \(MY = \alpha \cdot M \cdot L^{\alpha - 1} > 0\).

Next, I prove part (ii). I plug (D.2) into (D.3) and rearrange

\[
M \equiv -\frac{\partial L}{\partial \tau} = -\frac{\partial L_s}{\partial \tau} \cdot \frac{1}{1 + (\epsilon^s/\epsilon^d)} \quad (D.4)
\]

where \(\epsilon^s \equiv (\partial L_s/\partial \theta) \cdot (\theta/L^s) > 0\), \(\epsilon^d \equiv -(\partial L_d/\partial \theta) \cdot (\theta/L^d) > 0\). The next step is to express \(\epsilon^s\) and \(\epsilon^d\) as functions of endogenous variables. The definition of \(L^s(\theta, \tau)\) implies

\[
\epsilon^s = (1 - \eta) \cdot u + \frac{\lambda \cdot \epsilon^e}{\lambda + (1 - \lambda) \cdot s(\theta, \tau) \cdot f(\theta)} \quad (D.5)
\]

where \(\epsilon^e = (\partial s/\partial \theta) \cdot (\theta/s)\). The definition of the search function \(s(\theta, \tau)\) implies that \(\epsilon^e\) is constant and \(\partial s/\partial \theta > 0\). From Lemma 4 we have that \(d\theta/dA > 0\) and \(du/dA < 0\). Thus, \(\epsilon^s/dA < 0\).

The definition of labor demand in (20) implies

\[
\epsilon^d = \frac{\eta}{(1 - \alpha)} \cdot \left( \frac{[1 - \beta \cdot (1 - \lambda)] \cdot r/q(\theta)}{[1 - \beta \cdot (1 - \lambda)] \cdot r/q(\theta) + w/A} \right) \quad (D.6)
\]
Lemma 4 and the fact that \( q \) is decreasing in \( \theta \) imply that \( \frac{d\epsilon}{dA} > 0 \).

The definition of labor supply and the search function imply

\[
\frac{dL^s}{d\tau} \equiv \frac{\partial L^s}{\partial s} \cdot \frac{\partial \Delta U}{\partial \tau} = -\Omega \cdot u \cdot L, \tag{D.7}
\]

where \( \Omega \) is a constant. The last expression is increasing in \( A \) as long as \( L > [2 \cdot (1 - \lambda)]^{-1} \). This condition is always satisfied for a reasonable parametrization.\(^{56}\) We have that \( d(\frac{\partial L^s}{\partial \tau})/dA > 0 \), \( d\epsilon/s/dA < 0 \) and \( d\epsilon/dA > 0 \). Thus, \( dM/dA > 0 \).

\[ M_Y = \alpha \cdot M \cdot L^{\alpha - 1} \]

Thus, \( M_Y \) is increasing in \( A \) as long as \( L > [(1 + \alpha) \cdot (1 - \lambda)]^{-1} \). This condition is always satisfied for a reasonable parametrization.\(^{57}\)

### E Derivation of the New Keynesian Model

**Large Household.**—A measure 1 of identical workers are part of a large household with expected utility\(^{58}\)

\[
E_0 \sum_{t=0}^{\infty} \beta^t \cdot \left[ \ln(C_t) - (1 - (1 - \lambda) \cdot L^s_{t-1}) \cdot \Psi(s_t) \right], \tag{E.1}
\]

where \( E_0 \) is the expectation conditional on period-0 information. Workers pool their income before choosing consumption and saving. Employed workers pay a proportional labor income tax \( \tau_t \). The household’s budget constraint becomes

\[
P_t \cdot C_t + D_t = P_t \cdot w_t \cdot (1 - \tau_t) \cdot L_t + R_{t-1} \cdot D_{t-1} + P_t \cdot \phi_t + P_t \cdot T_t. \tag{E.2}
\]

\( P_t \) is the price level. \( D_t \) is the quantity of one-period government bonds purchased at time \( t \). \( R_{t-1} \) is the one-period gross nominal interest rate that pays off in period \( t \). The law of motion of the probability to be employed in period \( t \) is

\[
L^s_t = (1 - \lambda) \cdot L^s_{t-1} + (1 - (1 - \lambda) \cdot L^s_{t-1}) \cdot s_t \cdot f(\theta_t). \tag{E.3}
\]

The household chooses consumption \( \{C_t\}_{t=0}^{\infty} \) and search effort \( \{s_t\}_{t=0}^{\infty} \) to maximize utility subject to (E.2), (E.3) and the no-Ponzi-game constraint

\[
E_0 \left[ \lim_{t \to \infty} \frac{D_t}{\prod_{i=0}^{t-1} R_{i-1}} \right] \geq 0. \tag{E.4}
\]

\(^{56}\)A separation rate \( \lambda \) of 3 percent implies that the condition is satisfied as long as the employment rate \( L \) is above 51% percent. The condition even holds for an unrealistically high separation rate: a separation rate of 20% implies that the condition is satisfied as long as the employment rate \( L \) is above 63%.

\(^{57}\)A separation rate \( \lambda \) of 3 percent implies that the condition is satisfied as long as the employment rate \( L \) is above 62% percent. The condition even holds for an unrealistically high separation rate: a separation rate of 20% implies that the condition is satisfied as long as the employment rate \( L \) is above 75%.

\(^{58}\)Without government bonds, the setup is identical to search-and-matching model in Section 4.1.
Let \( \pi_t \equiv (P_t/P_{t-1}) - 1 \) be the inflation rate at time \( t \). The household’s optimal consumption path is given by the Euler equation

\[
C_t = \beta \cdot E_t \left[ \frac{R_t}{1 + \pi_{t+1}} \cdot C_{t+1} \right].
\] (E.5)

The household’s optimal search path is given by:

\[
\frac{\Psi'(s_t)}{f(\theta_t)} - \beta \cdot (1 - \lambda) \cdot E_t \left[ \frac{\Psi'(s_{t+1})}{f(\theta_{t+1})} \cdot [1 - s_{t+1} \cdot f(\theta_{t+1})] \right] = \Delta U_t
\] (E.6)

This equation implicitly defines optimal search effort as an increasing function of labor market tightness \( \theta_t \) and the utility gain from work \( \Delta U_t \). The search path \( E_t s_{t+1}/s_t \) is increasing in the expected job-finding probability in the future relative to today \( E_t f(\theta_{t+1})/f(\theta_t) \).

**Final Good Firms.**—A measure 1 of identical firms produce the final good and sell it on a perfectly competitive market. The representative final good firm uses \( y_t(i) \) units of each intermediate good \( i \in [0, 1] \) to produce \( Y_t \) units of final good with the production function

\[
Y_t = \left[ \int_0^1 y_t(i)^{(\epsilon-1)/\epsilon} di \right]^{\epsilon/(\epsilon-1)},
\] (E.7)

where \( \epsilon > 1 \) is the elasticity of substitution across intermediate goods. The final good firm takes as given the nominal price \( p_t(i) \) of each intermediate good and the nominal price \( p_t \) of the final good. The firm chooses \( y_t(i) \) for all \( i \in [0, 1] \) to maximize its profits

\[
P_t \cdot Y_t - \int_0^1 p_t(i) \cdot y_t(i) di.
\] (E.8)

The first-order condition with respect to \( y_t(i) \) is

\[
y_t(i) = Y_t \cdot \left( \frac{p_t(i)}{p_t} \right)^{-\epsilon}.
\] (E.9)

The equation describes the demand for intermediate good \( i \) as a function of the relative price \( p_t(i)/p_t \). Perfect competition in the final good market requires that the price of the final good equals its marginal cost of production:

\[
P_t = \left( \int_0^1 p_t(i)^{1-\epsilon} di \right)^{1/(1-\epsilon)}.
\] (E.10)

**Intermediate Good Firms.**—There is no entry or exit in the intermediate good section. Each intermediate good is produced by a monopolist. The monopolist uses \( L_t(i) \) units of labor to produce \( y_t(i) \) units of intermediate good \( i \) according to the production function

\[
y_t(i) = A_t \cdot L_t(i)^\alpha
\] (E.11)
As in Rotemberg (1982), the monopolist incurs a cost to adjust its nominal price given by

$$\gamma \cdot \left( \frac{p_t(i)}{p_{t-1}(i)} - 1 \right)^2 \cdot C_t, \quad (E.12)$$

where $\gamma$ captures the amount of resources devoted to adjusting prices. The price-adjustment cost is measured in units of the final good. It increases proportionally with the size of the economy, measured by $C_t$. The monopolist incurs a cost $r \cdot A_t$ to post a vacancy for one period. It hires $H_t(i) = L_t(i) - (1 - \lambda) \cdot L_{t-1}(i)$ workers in period $t$. Thus, it incurs a total cost of $r \cdot A_t / q(\theta_t) \cdot H_t$ to hire new workers in period $t$. The hiring cost is measured in units of the final good, and it increases proportionally with the state of technology $A_t$. The monopolist chooses $\{L_t(i)\}_{t=0}^\infty$ and $\{p_t(i)\}_{t=0}^\infty$ to maximize the expected sum of discounted real profits

$$E_0 \sum_{t=0}^\infty \frac{\beta^t}{C_t} \left[ \left( \frac{p_t(i)}{P_t} \right)^{1-\epsilon} \cdot Y_t - w_t \cdot L_t(i) - \frac{\gamma}{2} \cdot \left( \frac{p_t(i)}{p_{t-1}(i)} - 1 \right)^2 \cdot C_t - \frac{r \cdot A_t}{q(\theta_t)} \cdot H_t \right]. \quad (E.13)$$

Denote $\mu_t(i)$ the Lagrange multiplier on constraint (E.11) in period $t$. The first-order condition with respect to $L_t(i)$ is

$$\mu_t(i) \cdot \alpha \cdot L_t(i)^{\alpha-1} = \frac{w_t}{A_t} + \frac{r}{q(\theta_t)} - \beta \cdot (1 - \lambda) \cdot E_t \left[ \frac{C_t}{C_{t+1}} \cdot \frac{A_{t+1}}{A_t} \cdot \frac{r}{q(\theta_{t+1})} \right]. \quad (E.14)$$

The first order conditions with respect to $p_t(i)$ is

$$\frac{p_t(i)}{p_t} = \frac{\epsilon}{\epsilon - 1} \cdot \mu_t(i) + \frac{\gamma}{\epsilon - 1} \cdot \frac{C_t}{Y_t} \cdot \left( \frac{p_t(i)}{p_t} \right)^\epsilon \cdot \beta \cdot E_t \left[ \left( \frac{p_{t+1}(i)}{p_t(i)} - 1 \right) \cdot \frac{p_{t+1}(i)}{p_t(i)} \right] - \left( \frac{p_t(i)}{p_{t-1}(i)} - 1 \right) \cdot \frac{p_t(i)}{p_{t-1}(i)}. \quad (E.15)$$

$\mu_t(i)$ is the real marginal revenue of producing one unit of intermediate good $i$ in period $t$.

**Symmetric Equilibrium.**—In a symmetric equilibrium, all intermediate good firms are identical. Thus, $L_t(i) = L_t$, $y_t(i) = Y_t$, $p_t(i) = P_t$, and $\mu_t(i) = \mu_t$. Using the symmetry assumption, I rewrite aggregate labor demand from (E.14):

$$s \mu_t \cdot \alpha \cdot L_t^{\alpha-1} = \frac{w_t}{A_t} + \frac{r}{q(\theta_t)} - \beta \cdot (1 - \lambda) \cdot E_t \left[ \frac{C_t}{C_{t+1}} \cdot \frac{A_{t+1}}{A_t} \cdot \frac{r}{q(\theta_{t+1})} \right]. \quad (E.16)$$

The Philips curve is derived from (E.15):

$$\pi_t \cdot (\pi_t + 1) = \frac{1}{\gamma} \cdot \frac{Y_t}{C_t} \cdot [\epsilon \cdot \mu_t - (\epsilon - 1)] + \beta \cdot E_t[\pi_{t+1} \cdot (\pi_{t+1} + 1)]. \quad (E.17)$$

The aggregate production function is derived from (E.11):

$$Y_t = A_t \cdot L_t^\alpha. \quad (E.18)$$
Tax Multipliers in Hall (2005) and Pissarides (2000)

Hall (2005).—With constant returns to scale \( \alpha = 1 \). Other than that, the model is identical to the model in Section 4.1. Implicit differentiation of the first equilibrium condition in (24) yields

\[
\frac{d\theta}{dA} = \left[ \frac{\partial L^d}{\partial \theta} - \frac{\partial L^s}{\partial \theta} \right]^{-1} \cdot \frac{\partial L^d}{\partial A} = \frac{\theta}{A},
\]

where I have used that \( \epsilon^d = +\infty \) and \((\partial L^d/\partial A) \cdot (A/L^d) = +\infty \). The signs of the derivatives are from Lemma 2 and Lemma 3. Thus, \( d\theta/dA > 0 \). The other results follow, because \( L = L^s(\theta, \tau) \) and \( u = 1 - (1 - \lambda) \).

I now calculate the effect of a tax cut. Implicit differentiation of the first equilibrium condition in (24) yields

\[
\frac{d\theta}{d\tau} = -\left[ \frac{\partial L^s}{\partial \tau} - \frac{\partial L^d}{\partial \tau} \right]^{-1} \cdot \frac{\partial L^s}{\partial \theta} = 0,
\]

where I have used that \( \epsilon^d = +\infty \). The signs of the derivatives are from Lemma 2 and Lemma 3. Thus, \( d\theta/d\tau > 0 \). Implicit differentiation of the second equilibrium condition in (25) yields

\[
\frac{\partial L}{\partial \tau} = \frac{\partial L^s}{\partial \theta} \cdot \frac{d\theta}{d\tau} + \frac{\partial L^s}{\partial \tau}.
\]

Thus, \( \frac{\partial L}{\partial \tau} < 0 \). It follows that \( M > 0 \), and \( M^Y = \alpha \cdot M \cdot L^{\alpha - 1} > 0 \). Proposition 1 establishes that \(-\partial L^s/\partial \tau\) is increasing in \( A \). Thus, \( M \) is increasing in \( A \).

Pissarides (2000).—The model has constant returns to scale \( \alpha = 1 \) and the wage is flexible. Other than that, the model is identical to the model in Section 4.1. The model now has endogenous variables: employment \( L \), labor market tightness \( \tau \) and the wage \( w \). Equilibrium labor market tightness equalizes quasi-labor supply and aggregate labor demand:

\[
L^s(\theta, \tau, w) = L^d(\theta, A, w).
\]

Equilibrium employment is obtained from aggregate labor supply:

\[
L = L^s(\theta, \tau, w).
\]
wage \( w \). Worker and firm split the total surplus. Thus, the third equilibrium condition is

\[
w = A - \frac{1 - \chi}{\chi} \cdot \Delta U.
\]  

(F.6)

I consider the effect of an increase in \( A \). Implicit differentiation of (F.4) yields

\[
\frac{d\theta}{dA} = \frac{\theta}{A} - \frac{\theta}{w} \cdot \frac{dw}{dA} = \frac{\theta}{A \cdot w} \cdot (w - \chi \cdot A),
\]  

(F.7)

where I have used that \( \epsilon^d = +\infty \), \( (\partial L^d/\partial A) \cdot (A/L^d) = +\infty \), \( (\partial L^d/\partial w) \cdot (w/L^d) = -\infty \), and \( dw/dA = \chi \) from implicit differentiation of (F.6). From (F.6) we have that \( w = \chi A + (1 - \chi) \cdot t \). Thus, \( d\theta/dA > 0 \).

Implicit differentiation of (F.5) yields

\[
\frac{\partial L}{\partial A} = \frac{\partial L^s}{\partial \theta} \cdot \frac{d\theta}{dA} + \chi \cdot \frac{\partial L^s}{\partial w}.
\]  

(F.8)

The sign of \( \partial L^s/\partial \theta \) is from Lemma 3. The sign of \( \partial L^s/\partial w \) follows from the properties of the optimal search effort \( s(\theta, \Delta U) \) in (22). Thus, \( dL/dA > 0 \).

Next, I consider the effect of a tax cut. Implicit differentiation of (F.4) yields

\[
\frac{d\theta}{d\tau} = -\frac{\theta}{w} \cdot (1 - \chi).
\]  

(F.9)

where I have used \( \epsilon^d = +\infty \), \( (\partial L^d/\partial w) \cdot (w/L^d) = -\infty \), and \( dw/d\tau = (1 - \chi) \) from implicit differentiation of (F.6). Thus, \( d\theta/d\tau < 0 \). Implicitly differentiating (F.5) and plugging in for \( d\theta/d\tau \) yields

\[
M = -\frac{\partial L}{\partial \tau} = (1 - \chi) \cdot \epsilon^s \cdot \frac{L}{w} - \frac{\partial L^s}{\partial \tau},
\]  

(F.10)

From \( d\theta/dA > 0 \) and Proposition 1, we have that \( -\partial L^s/\partial \tau \) is increasing in \( A \). From Proposition 1, we also have that \( d\epsilon^s/dA < 0 \). Because \( dw/dA > 0 \), \( \partial L/\partial A > 0 \) and the fact that firms produce with constant returns to scale, we have that \( L/w \) is decreasing in \( A \). Thus, whether \( M \) is increasing in \( A \) is ambiguous. The multiplier of the flexible wage model coincides with Hall (2005) if workers have full bargaining power \( \chi = 1 \).