State dependent government spending multipliers: Downward nominal wage rigidity and sources of business cycle fluctuations*

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Abstract

We consider a New Keynesian model with downward nominal wage rigidity (DNWR) and show that government spending is much more effective in stimulating output in a low-inflation recession relative to a high-inflation recession. The government spending multiplier is large when DNWR binds, but the nature of recession matters due to the opposing response of inflation. In a demand-driven recession, inflation falls, preventing real wages from falling, leading to unemployment, while inflation rises in a supply-driven recession limiting the consequences of DNWR on employment. We document supporting empirical evidence, using both historical time series data and cross-sectional data from U.S. states.

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1 Introduction

The recent periods of low interest rates have shown that fiscal policies are crucial for economic recovery and understanding the effects of increased government spending on the economy is of great importance, particularly for policymakers. This information is summarized in terms of multipliers, that quantify the rise in output as a result of a $1 increase in government spending. Recently, the literature has made great strides in going beyond the average effects of government spending, and distinguishing the impact based on the state of the underlying economy. Empirical research on the state-dependence of the fiscal multiplier is an active area of research, with a lack of consensus on the relative state dependencies in the effectiveness of government spending across good and bad times.[1] Moreover, our understanding of the fiscal transmission at play across different states of the economy is relatively limited.

This paper contributes to both the empirical and theoretical literature on the state-dependence of government spending. While the earlier literature has focused on whether the multipliers are higher when there is slack in the economy, this paper establishes that the interactions of unemployment and inflation matter in determining the government spending multipliers. In particular, the government spending multiplier is different across recessions, based on whether they coincide with high or low inflation relative to the trend.

We propose a New Keynesian model featuring downward nominal wage rigidity (DNWR) with two different sources of business cycle fluctuations: demand and supply shocks.[2] In an expansion, the usual effects of government spending prevail in the model, with consumption being crowded out due to negative wealth effects and rising real interest rate due to higher inflation. The DNWR constraint becomes relevant during a recession. Nominal wages being rigid downwards means that in a recession, nominal wages cannot fall and real wages can be possibly higher than the market clearing real wage, leading to an increase in unemployment. In determining real wages, nominal wages as well as the price levels matter. The two different sources of fluctuations lead to a price level response in opposing directions in recessions. As a consequence, the labor market outcome differs across the two types of recessions: demand-driven vs. supply-driven recession. For example, in a demand-driven recession, inflation falls and

[1] See, for example, Auerbach and Gorodnichenko (2012), Nakamura and Steinsson (2014), and Ramey and Zubairy (2018).

[2] The presence of DNWR in the US is well documented, for example, Card and Hyslop (1996); Kahn (1997); Lebow, Sacks, and Anne (2003); Barattieri, Basu, and Gottschalk (2014); Daly and Hobijn (2014); Fallick, Lettau, and Wascher (2016); Kurmann and McEntarfer (2018); Grigsby, Hurst, and Yildirmaz (2019); Hazell and Taska (2020); Murray (2019); Jo (2021).

thus DNWR prevents real wages from falling. As real wages are higher than the optimal level, expansionary fiscal policy does not increase wages or marginal cost of production immediately in a recession. Thus, it does not lead to a rise in inflation and subsequently the real interest rate. As a consequence, it leads to less crowding-out effects and a larger government spending multiplier than in an expansion. On the other hand, in a supply-driven recession, inflation goes up, and thus even if the DNWR constraint binds, it has a limited impact on real wages. As a result, increased government spending is relatively less effective in stimulating output in a supply-driven recession.

We first solve the model analytically to highlight the mechanism which gives rise to a higher spending multiplier when DNWR binds. This analytical model also helps us illustrate that in addition to the source of fluctuations, the size and sign of government spending also affect the resulting multiplier. In our quantitative model, when we simulate a deep recession to match the trough of the Great Recession, the government spending multiplier is 1.7 in a demand-driven recession, and 0.54 in a supply-driven recession and during expansions, since DNWR does not bind in a supply-driven recession or in an expansion. We further explore the robustness of these results for alternative preferences and underlying assumptions about the size of the recession or the fiscal interventions, among other features.

Next, we provide empirical evidence to support these findings. We first focus on time series evidence based on historical macroeconomic data for the United States, following Ramey and Zubairy (2018). This long time series data spanning 1889 to 2015 helps us to exploit time variation in government spending, and also allows us to distinguish between periods of high unemployment accompanied with high and low inflation historically. Consistent with our model predictions, we find evidence that the government spending multiplier is statistically significantly larger in a high unemployment period accompanied with low inflation relative to the trend, classified as a demand-driven recession, than a high unemployment period accompanied with high inflation relative to the trend, i.e. a supply-driven recession. In addition, we also document that there is no evidence of difference in multipliers based on inflation in the low unemployment periods, which also supports DNWR as the potential mechanism that becomes relevant only in bad times.

We also conduct a regional analysis, exploiting variation in military procurement contracts across U.S. states, for the sample period 1966 to 2018, in the spirit of Nakamura and Steinsson (2014) to provide further empirical support for our findings. The U.S. state-level analysis is useful to show how the effects of government spending vary depending on the relative business cycle conditions after controlling for any aggregate general equilibrium effects. The time fixed effects in the regional analysis successfully control for any changes in the monetary policy regime or taxes and financing responses to changes in government spending. We find that the effects of government spending on the economy are larger in periods when the employment rate is low, and particularly when it coincides with low inflation. Notably, this regional approach also allows us to exploit a new data set quantifying a DNWR measure across U.S. states from Jo (2021) to test our proposed mechanism directly. We find larger effects of government spending when low employment coincides with states facing higher level of DNWR, and low inflation, conditions that would satisfy a demand-driven recession in our theoretical setting.

The paper has four contributions. In our theoretical model, we rely on downward nominal wage rigidity (DNWR) as a key mechanism. In a model with DNWR, the response of real wages is of primary importance in driving unemployment in the model. We firstly show that the difference in the response of inflation across demand and supply shocks leads to different consequences for real wages even if the nominal wages are downwardly bound across the two cases. Thus, the frictions in real wages transmitted by the joint behavior of nominal wages and inflation are at the heart of exploiting DNWR as a way to generate asymmetries in the business cycle.[3]

Second, as a consequence of these findings, we show that the source of fluctuation matters for the size of the fiscal multiplier, particularly in a recession. The distinction between good and bad times alone might not be sufficient when considering the state-dependent government spending multiplier and the shocks driving the recession constitute an important factor. Notably, the same increase in government spending will have a larger output multiplier in a low-inflation recession driven by demand shocks, versus one where the recession is accompanied with high inflation driven by supply shocks.

Some well-established methodologies that have considered state dependence of the government spending multipliers exploiting historical time series or cross-sectional data have found limited evidence of larger multipliers across periods of slack in the economy. Our third contribution is to exploit rich historical data to show that these same estimation strategies yield statistically significantly larger multipliers in periods of slack accompanied with low inflation relative to high unemployment periods with high inflation, in line with our theoretical framework. This also potentially helps to reconcile some disagreement on the relative size of the spending multipliers in a recession versus an expansion, depending on the choice of the dataset with differing nature of recessions.

Lastly, our cross-sectional analysis employing U.S. state-level data also allows us to

[3]See related insights in Benigno and Ricci (2011); Schmitt-Grohé and Uribe (2016, 2017); Dupraz, Nakamura, and Steinsson (2019)

test the mechanism from our theoretical model directly, as we use a new data set quantifying a DNWR measure across U.S. states over time. We show that the local spending multiplier is larger in a demand-driven recession with a high degree of DNWR than in a supply-driven recession, which is consistent with our theoretical predictions.

1.1 Related Literature

Our model contributes to the small but growing literature on theoretical explanations behind variations in the size of the government spending multipliers based on the state of the economy.[4] Shen and Yang (2018) show in a New Keynesian model that the government spending multipliers can be higher in a recession than in a boom when there are downward nominal wage rigidity constraints.We build on the insights in this paper and add supply side considerations which provide new crucial results. Michaillat (2014) generates countercyclical multipliers of government spending in a search and matching model, focusing on public employment. During high unemployment periods, the rise in public employment increases labor market tightness to a small degree and also has a smaller crowding out effect on private employment. Albertini, Auray, Bouakez, and Eyquem (2020) consider a model with involuntary unemployment, incomplete markets and nominal rigidities. They are able to generate state-dependent government multipliers as increased spending reduces unemployment and thus unemployment risk and precautionary savings to a greater extent during high unemployment periods. In departure from this literature, we further distinguish between the nature of a recession and establish that the interactions between unemployment and inflation play a critical role in the magnitude of the multiplier during a period of high unemployment.

The closest paper to our analysis is Ghassibe and Zanetti (2020) that also presents a model of differential fiscal multiplier depending upon the source of shock.[5] Their model features search and matching frictions in a goods market. Goods market tightness increases in a demand boom, and decreases in a supply boom. The demand side fiscal

[4]A larger strand of the theoretical literature has considered how the stance of monetary policy affects the government spending multiplier. Notably, they show in a New Keynesian model, the spending multipliers are much larger at the ZLB than in normal times. See, for example, Christiano et al. (2011), Woodford (2011), and Eggertsson (2011). Somewhat related to our work on distinguishing between sources of fluctuations, Mertens and Ravn (2014) find that the size of the fiscal multiplier depends on the type of shock that pushed the economy into the liquidity trap. In particular, they show that when the liquidity trap is due to a non-fundamental shock, supply-side fiscal instruments have a large multiplier, and demand-side fiscal instruments have a small multiplier. The reverse is true when the liquidity trap is caused by a fundamental shock.

[5]Notably, they find that policies stimulating aggregate demand, like increased government spending is more effective in demand-driven recessions relative to supply-driven recessions. On the other hand policies affecting aggregate supply have the larger multipliers in supply-driven recession than demand riven recession.

multiplier is countercyclical under demand-side fluctuations since the crowding-out effect is stronger when the market is tighter. They provide empirical support for their findings by estimating spending and tax cut multipliers in recessionary and expansionary episodes, conditional on those being either demand or supply-driven, by distinguishing between the comovement of economic activity and inflation. However, we differ in the main friction of the model - our study examines the role of DNWR. While Ghassibe and Zanetti (2020) use a real model, we present a model with nominal frictions which predicts comovement between output and inflation, allowing us to identify the sources of the business cycle. We also present empirical findings in line with theoretical results on unemployment, inflation, and DNWR.

Downward nominal wage rigidity have been explored as a way to generate the asymmetric multipliers, considering differences in response to expansionary versus contractionary government spending beyond the state of the economy. Barnichon, Debortoli, and Matthes (2020) consider a model with incomplete markets and DNWR and generate asymmetric and state-dependent effects of the government spending multipliers. In a small open economy model with DNWR, Born, D'Ascanio, Müller, and Pfeifer (2019) show that the real exchange rate and output respond asymmetrically to negative and positive government spending shocks under a peg, and support their theoretical results with empirical findings. Our work differs in further emphasizing the role of the source of fluctuation in characterizing the state-dependent government spending multipliers.[6]

Our paper also contributes to the large empirical literature on state-dependent fiscal policy, notably one that explores whether the government spending multiplier differs based on the state of the economy. Some notable studies like Auerbach and Gorodnichenko (2012) and Auerbach and Gorodnichenko (2013) find distinctly larger spending multipliers in recessions than in expansions. Ramey and Zubairy (2018), on the other hand, do not find multipliers larger than 1 in any state of the economy, and limited evidence of significantly larger multipliers during periods of slack. We extend this analysis to show that conditioning on the interactions between inflation and unemployment is important and find evidence of spending multipliers close to 1 in a demand-driven recession, which is statistically significantly larger than the multipliers in expansions and supply-driven recessions.

Defense contracts have been used to identify the cross-sectional local multipliers by many others,[7] most notably by Nakamura and Steinsson (2014). However, the focus has

[6] In our analytical and quantitative model, we also briefly touch upon how the sign of government spending affects the size of the spending multiplier based on the state of the economy and the nature of a recession.

[7] Dupor and Guerrero (2017), Auerbach, Gorodnichenko, and Murphy (2019), Demyanyk, Loutskina,

been on quantifying local multipliers, their spillovers effects and potentially the mapping to the aggregate multiplier. See Chodorow-Reich (2019) for a survey of this local multiplier literature that exploits state-level variation. Bernardini, De Schryder, and Peersman (2020) use U.S. state level data to study the effects of fiscal policy in the decade surrounding Great Recession, and find larger multipliers when a state is in a recession or had a high level of household indebtedness. Our paper uses US states-year panel data to identify the state-dependent local multipliers depending upon the source of the business cycle. We further exploit the US state-level degree of DNWR to show empirical findings consistent with our model results, namely that the local multiplier is higher in a US state with a high degree of DNWR in a low inflation recession.

The remainder of the paper is organized as follows. Section 2 introduces a New Keynesian model with DNWR. We examine the analytical solution in Section 2.3. Section 3 presents quantitative results that the spending multipliers depend on the state of the economy and source of fluctuations. Section 4 and Section 5 provide empirical evidence of our proposed model with historical time series data and US state-level annual panel data, respectively. Section 6 concludes.

2 New Keynesian model featuring DNWR

Our baseline model is a New Keynesian model with government spending subject to a DNWR constraint, featuring two sources of the business cycle. Shen and Yang (2018) introduce a DNWR constraint into the New Keynesian model with government spending, with a preference shock. We extend this model by adding supply side considerations, by including a productivity shock. While DNWR is the main mechanism in our model to generate asymmetry, we show how the degree to which it binds depends on the source of business cycle fluctuations. We also show how in a model with DNWR, inflation helps to grease the wheels of the labor market. The two types of shocks, demand and supply have different implications for inflation, and we show how inflation can mitigate the role of DNWR on employment.

2.1 Households

A representative households chooses consumption c_t, labor n_t, and nominal bonds B_t to maximize utility over an infinite time horizon:

$$\max \mathbb{E}_0 \sum_{t=0}^{\infty} \prod_{j=0}^{t} \beta_j \frac{[c_t - \chi(n_t)^{\varphi}]^{1-\sigma}}{1-\sigma},$$

and Murphy (2019), and Auerbach, Gorodnichenko, and Murphy (2020), among others.

where β_j is the time varying discount factor in period j. σ is the inverse of the intertemporal elasticity of substitution and $1/(\varphi - 1)$ is the Frisch elasticity of labor supply. We consider GHH (Greenwood, Hercowitz, and Huffman (1988)) preferences that imply no wealth effect on labor supply.[8] There are a continuum of consumption goods $c_t(i)$ where $i \in [0, 1]$. The composite consumption is aggregated with the Dixit and Stiglitz (1977) aggregator, $c_t = \left(\int_0^1 c_t(i)^{\frac{\theta-1}{\theta}} di \right)^{\frac{\theta}{\theta-1}}$. Households are subject to the following period t budget constraint,

$$P_t c_t + B_t + T_t = W_t n_t + R_{t-1} B_{t-1} + \int_0^1 \Gamma(i) di,$$

where P_t is the aggregate price index, B_t is nominal bond, T_t is lump-sum tax, W_t is the nominal wage rate, and R_{t-1} is the nominal interest rate between $t-1$ and t, and $\Gamma(i)$ is the profit from ownership of firm i.

We assume that nominal wage adjustment is constrained downwardly, as proposed by Schmitt-Grohé and Uribe (2016).

$$W_t \geq \gamma W_{t-1}, \qquad \gamma > 0. \tag{1}$$

The parameter γ governs the degree of DNWR. Nominal wages cannot fall below the previous period's wage when γ is greater than one, while nominal wages are fully flexible when γ is zero. If we assume $\gamma > 0$, nominal wages are not fully flexible and the labor market does not clear all the time. Actual employment used for production (n_t) can be lower than labor supply (n_t^s) when a shock drives the DNWR constraint to bind. Nominal wages and employment must satisfy the complementary slackness condition:

$$(n_t^s - n_t)(W_t - \gamma W_{t-1}) = 0. \tag{2}$$

When the DNWR constraint is not binding $(W_t > \gamma W_{t-1})$,the labor market clears $(n_t^s = n_t)$ and unemployment rate is zero. When the DNWR constraint is binding, there is involuntary unemployment $(n_t < n_t^s)$, as the households' willingness to work at the prevailing wage is larger than labor demand. We define the unemployment rate as, $u_t = \frac{n_t^s - n_t}{n_t^s} \times 100$.

[8] We have also conducted the quantitative analysis with King, Plosser, and Rebelo (1988) preferences, that allow for a wealth effect on labor supply, also. Our main findings follow through and the results are shown in Table 3 in 3.3.3.

2.2 Firms

The final good y_t is produced with a continuum of intermediate goods, $y_t(i)$, $i \in [0,1]$, with the technology:

$$y_t = \Big(\int_0^1 y_t(i)^{\frac{\theta-1}{\theta}} di\Big)^{\frac{\theta}{\theta-1}}.$$

Firms in this market operate under perfectly competitive conditions. Profits are given by

$$P_t y_t - \int_0^1 p_t(i) y_t(i) di.$$

Firms maximize profits subject to the above production technology. The implied demand functions for intermediate goods are $y_t(i) = (p_t(i)/P_t)^{-\theta} y_t$. Perfect competition drives profits to zero. As a consequence, the price level is given by $P_t = \left[\int_0^1 p_t(i)^{1-\theta} di\right]^{\frac{1}{1-\theta}}$.

Intermediate good i is produced using labor:

$$y_t(i) = A_t n_t(i), \tag{3}$$

where A_t is technology. Given the output level $y_t(i)$ chosen in period t, cost minimization implies marginal cost as given by $mc_t(i) = w_t/A_t$. Following Calvo (1983) and Yun (1996), a fraction $1-\omega$ of intermediate firms can optimally choose their prices each period. Firms that get a chance to reset their prices in period t choose their price to maximize the expected sum of discounted future profits. Suppose firm i has the chance to adjust the price in period t and let $P_t^*(i)$ be the chosen price. Then, $P_t^*(i)$ is set so as to maximize

$$\max_{P_t^*(i)} \mathbb{E}_t \sum_{j=0}^{\infty} \omega^j \lambda_{t,t+j} y_{t,t+j}(i) [\frac{P_t(i)^*}{P_{t+j}} - mc_{t+j}(i)]$$

subject to demand for intermediate goods $y_{t,t+j}(i) = \left(P_t^*(i)/P_{t+j}\right)^{-\theta} y_{t+j}$, where $\lambda_{t,t+j} = \mathbb{E}_t \prod_{k=1}^{j} \beta_{t+k} \frac{\lambda_{t+j}}{\lambda_t}$ is the stochastic discount factor for real j-period ahead profit. The full set of optimizing conditions characterizing the equilibrium are shown in the Appendix A.1.

2.3 Fiscal and monetary policy

Monetary policy follows the Taylor rule, and the gross nominal interest rate R_t responds to the deviations of the inflation rate from its steady state, which is summarized as

$$R_t = R(\frac{\pi_t}{\pi})^{\alpha_\pi},$$

where π denotes the steady-state level of inflation. The government collects lump-sum taxes T_t to balance the government budget constraint each period:

$$g_t = \frac{T_t}{P_t}.$$

The aggregate market clearing condition is[9]

$$y_t = c_t + g_t.$$

Analytics of state-dependent spending multipliers

In this section, we solve the model analytically to describe the main mechanisms at play in the model. These analytical results help illustrate how the government spending multipliers depend on the state of the economy and inflation jointly. For tractability purposes, we assume that $\gamma = 1$, i.e. absolute DNWR, which means that nominal wages can not adjust downward. We consider a one-time government spending shock ($\widehat{g}_t$=$\widehat{g}_t$ and $\mathbb{E}_t\widehat{g}_{t+1}$=0).

We log-linearize the equilibrium conditions and summarize them into two equations: the IS curve and the Phillips curve. The model has two equilibria depending on the labor market output: full-employment and slack. Each equilibrium is associated with a different Phillips curve (PC) while the IS curve stays the same. The IS curve can be written as

$$\widehat{y}_t = \mathbb{E}_t\widehat{y}_{t+1} - (\theta - 1)(\widehat{a}_t - \mathbb{E}_t\widehat{a}_{t+1}) + \theta s_g(\widehat{g}_t - \mathbb{E}_t\widehat{g}_{t+1}) - \Psi(\alpha_\pi\widehat{\pi}_t - \mathbb{E}_t\widehat{\pi}_{t+1}) - \Psi\mathbb{E}_t\widehat{\beta}_{t+1}, \quad (4)$$

where hat variables stand for log-deviations from the steady state.[10] When the DNWR constraint does not bind, or in the full employment equilibrium, the PC is

$$\widehat{\pi}_t = \frac{(1-\omega)(1-\omega\beta)}{\omega}(\varphi - 1)\widehat{y}_t - \frac{(1-\omega)(1-\omega\beta)}{\omega}\varphi\widehat{a}_t + \beta\mathbb{E}_t\widehat{\pi}_{t+1}. \quad (5)$$

The marginal cost depends on the level of current production at the full-employment equilibrium. In contrast, when the DNWR constraint binds, the PC becomes the following,

$$\widehat{\pi}_t = \frac{(1-\omega)(1-\omega\beta)}{\omega + (1-\omega)(1-\omega\beta)}[\widehat{w}_{t-1} - \widehat{a}_t] + \frac{\omega\beta}{\omega + (1-\omega)(1-\omega\beta)}\mathbb{E}_t\widehat{\pi}_{t+1}, \quad (6)$$

[9]We have purposely kept the model simple in order to be able to drive analytical results in the next section. However, we can show in the context of our quantitative model that the overall results are unaffected if we consider capital as an input in the production function and thus include investment in the model or if we consider distortionary taxes instead of lump-sum taxes to finance government spending.

[10]$\Psi = (\theta\varphi(1 - s_g) - \theta + 1)/\sigma\varphi$ and s_g is the steady state government spending to GDP ratio.

where the marginal cost is a function of the wage from the previous period. Consequently, the economy is in the slack equilibrium, suffering from involuntary unemployment. Detailed derivations of log approximation of the equilibrium conditions are available in Appendix A.1.1. Now let's consider the business cycles from two sources of shocks - a preference shock ($\widehat{\beta}_{t+1}$) and a productivity shock ($\widehat{a}_t$).

Assumption 1. The sequences of the preference shock ($\mathbb{E}_t\widehat{\beta}_{t+1} = b_L < 0$ and $\mathbb{E}_t\widehat{\beta}_{t+2} = 0$) and ($\mathbb{E}_t\widehat{\beta}_{t+1} = b_H > 0$ and $\mathbb{E}_t\widehat{\beta}_{t+2} = 0$) cause a demand-driven expansion and recession, respectively, in period t. The sequence of the technology shock ($\widehat{a}_t = a_H > 0$, $\mathbb{E}_t\widehat{a}_{t+1}=\rho_a a_H$, and $\mathbb{E}_t\widehat{a}_{t+2}=a_L$) and ($\widehat{a}_t = a_L < 0$, $\mathbb{E}_t\widehat{a}_{t+1}=\rho_a a_L$, and $\mathbb{E}_t\widehat{a}_{t+2}=a_H$) drive a supply-driven expansion and recession, respectively, in period t.

A negative preference shock ($\widehat{\beta}_{t+1} = b_L$) generates a demand-driven expansion. When the discount factor is lower, households prefer to increase consumption in the current period, increasing demand for goods. This increase in goods demand raises labor demand in a monopolistic competition model, with an increase in real wages, and thus marginal cost, leading to higher inflation. A positive preference shock ($\widehat{\beta}_{t+1} = b_H$), in contrast, leads consumers to postpone their consumption, resulting in a demand-driven recession. On the other hand, a positive productivity shock ($\widehat{a}_t = a_H$) raises the marginal product of labor, leading to an increase in supply of goods, which generates a supply-driven expansion in output. A negative productivity shock ($\widehat{a}_t = a_L$) causes a supply-driven recession. Unlike the preference shock, we assume a persistent productivity shock in order to ensure a positive response of output to a positive productivity shock, which we will discuss in the proof of Proposition 1 in Appendix A.1.2 in detail.[11]

Proposition 1. In response to a preference shock, output ($\widehat{y}_t$) and inflation ($\widehat{\pi}_t$) co-move, and in response to a technology shock, output and inflation move in the opposite direction. That is,

$$\frac{\partial \widehat{y}_t}{\partial \widehat{\beta}_{t+1}} < 0; \frac{\partial \widehat{\pi}_t}{\partial \widehat{\beta}_{t+1}} < 0, \text{ and } \frac{\partial \widehat{y}_t}{\partial \widehat{a}_t} > 0; \frac{\partial \widehat{\pi}_t}{\partial \widehat{a}_t} < 0.$$

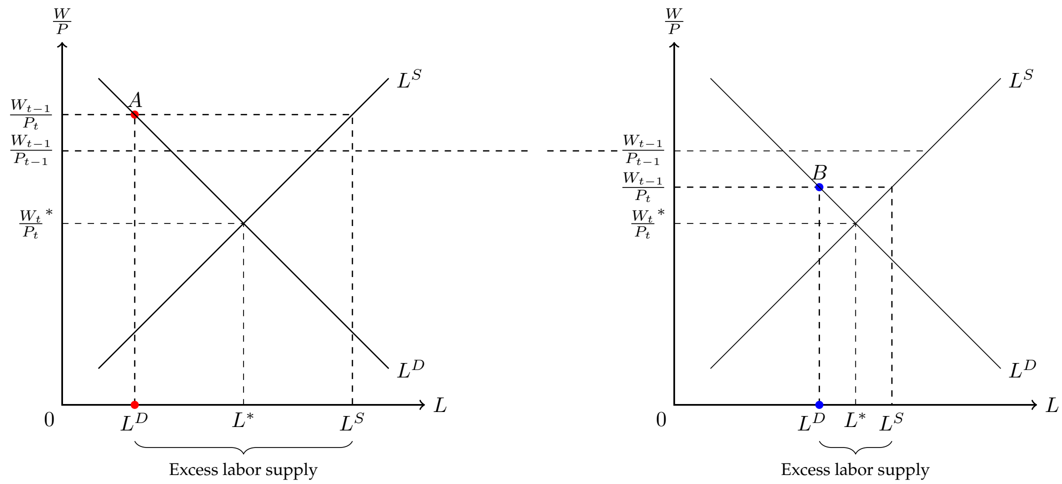
Proof. The proof is available in Appendix A.1.2.[12] □

[11] There is also empirical evidence to support the fact that a productivity shock is more persistent than a preference shock. A vast literature uses a unit root process for technology shocks and others estimate the autoregressive parameter to be large, as discussed in more detail when we calibrate the quantitative model.

[12] Proposition 1 holds under the following assumptions on parameter values. The elasticity of substitution parameter θ is greater than 1, the discount factor β is less than 1 and greater than zero. The government spending share in output, s_g is less than one. The intertemporal elasticity of substitution σ is assumed to be greater than one, while the frequency of price adjustment is ω is less than one. The Taylor coefficient on inflation is assumed to be higher than one. The persistence of productivity shock ρ_a lies between zero and one, but needs to be high enough to ensure that output rises in response to a positive technology shock.

Figure 1: Labor market equilibrium in a demand-driven vs. supply-driven recession

(a) In a demand-driven recession　　(b) In a supply-driven recession



Notes: The figure illustrates labor market outcomes in a demand-driven recession (left panel) and a supply-driven recession (right panel). Both recessions result in a market clearing real wage that is lower than the previous real wage. The opposite responses of inflation in both recessions lead to different labor market equilibrium. Points A and B represent the labor market equilibrium in a demand-driven and supply-driven recession, respectively.

This difference in the inflation response across preference and productivity shock recessions plays a crucial role in determining labor market outcomes in the presence of DNWR. For example, Figure 1 describes the labor market equilibrium in a demand-driven and a supply-driven recession across the two panels. In a recession, assume that the real wage (W_{t-1}/P_{t-1}) from the previous period is higher than the current market-clearing real wage $(W_t/P_t)^*$ due to either a positive discount factor shock (shown in Figure 1a) or a negative productivity shock (shown in Figure 1b) in period t.[13] In any recession, nominal wage is not allowed to adjust downwardly since the DNWR constraint imposes $W_t \geq \gamma W_{t-1}$, where $\gamma = 1$. In contrast, price inflation responds immediately. In response to a contractionary discount factor shock, the resulting lack of demand lowers the price level.[14] This further raises the real wage and reduces the labor demanded. Point A in Figure 1a represents the combination of real wage and labor used in production in a demand-driven recession. On the other hand, when there is a negative productivity shock, the marginal product of labor goes down, and marginal cost goes up, henceforth, resulting in inflation. This increase in price level lowers real wages, and point B in Fig-

[13]Note that the previous real wage (W_{t-1}/P_{t-1}) and the current market clearing wage $(W_t/P_t)^*$ in both figures are assumed to be the same.

[14]Given a zero steady-state inflation rate, lower inflation relative to the steady-state means deflation.

ure 1b becomes a labor market outcome in a supply-driven recession. For both cases, the quantity of labor demand (L^D) is less than the quantity of labor supply (L^S), leading to an excess labor supply. The equilibrium level of labor is demand-determined in the recession, or $L = L^D = \min\{L^D, L^S\}$ as $L^D \leq L^S$ when DNWR binds. From this example, we can clearly see that inflationary pressure in a supply-driven recession helps adjust real wages downwardly when the DNWR constraint binds. As a result, the equilibrium quantity of labor used in production is higher in a supply-driven recession than in a demand-driven recession, and there is excess labor supply or larger involuntary unemployment in a demand-driven recession.

Proposition 2. In a model without DNWR, the government spending multiplier takes the same value M_y in expansion and recession states, i.e. is acyclical.

Proof. The government spending multiplier is

$$M_y \equiv \frac{\partial \widehat{y}_t}{\partial \widehat{g}_t} \frac{1}{s_g} = \frac{\omega\theta}{\omega + \Psi\alpha_\pi(1-\omega)(1-\omega\beta)(\varphi-1)} \geq 0,$$

regardless of the shock processes and the state of the economy. Under the typical calibrated parameter values, $M_y \geq 0$. The detailed proof is available from Appendix A.1.2. □

In the absence of the DNWR constraint, the model reduces to a standard new Keynesian model and is fully symmetric and the government spending multiplier is acyclical, as stated in Proposition 2. An increase in government spending raises aggregate demand, which leads to an increase in labor demand, given nominal price rigidities. This leads to a higher wage rate and labor, leading to an overall rise in output.[15]

Next we consider the case where a contractionary preference or technology shock hits the economy such that it leads to the DNWR constraint binding.

Proposition 3. When DNWR binds in period t under the expectation of achieving full employment in period $(t+1)$, the spending multiplier is M_{DNWR} , which is bigger than M_y – the multiplier when DNWR does not bind.

Proof. When the DNWR constraint binds, we show that the government spending multiplier for output is

[15]Under our assumption of GHH preferences, we eliminate any movement in the labor supply curve due to negative wealth effects. The importance of these preferences is apparent if we consider a flexible price case, where $\omega = 0$, which results in a multiplier of zero, since both labor supply and labor demand do not respond to an increase in government spending.

$$M_{DNWR} = \theta > M_y = \frac{\omega\theta}{\omega + \Psi\alpha_\pi(1-\omega)(1-\omega\beta)(\varphi-1)}$$

Detailed proof is available in Appendix A.1.2. □

Proposition 3 shows that the government spending multiplier is more effective when DNWR is a binding constraint. As long as the DNWR constraint binds, an increase in government spending raises equilibrium labor used in production without increasing nominal wage. When the DNWR constraint does not bind, an increase in labor demand raises wage, diluting the effect of a rightward shift in labor demand on equilibrium labor. On the other hand, there is no inflationary pressure on price with the binding DNWR constraint since real wages, henceforth, marginal cost do not change.[16] The real interest rate thus stays the same, ruling out crowding out effects on private consumption.[17] Overall, we document that government spending is more effective as long as the DNWR constraint binds because 1) it increases labor without raising nominal wages and 2) it does not raise real interest rate. Thus, the government spending multiplier is state-dependent in the presence of DNWR. In an expansion, nominal wages go up and DNWR does not bind, whereas the DNWR constraint binds in a recession. Thus, based on Proposition 3, a spending multiplier can be higher in a recession than in an expansion.

Lemma 1. Assume the economy is at the steady-state in period $t-1$, $\widehat{w}_{t-1} = 0$. In the presence of the DNWR constraint ($\gamma = 1$), a positive discount factor shock or a negative productivity shock triggers the DNWR constraint to bind and induces unemployment in period t.

Proof. The proof is available in Appendix A.1.2. □

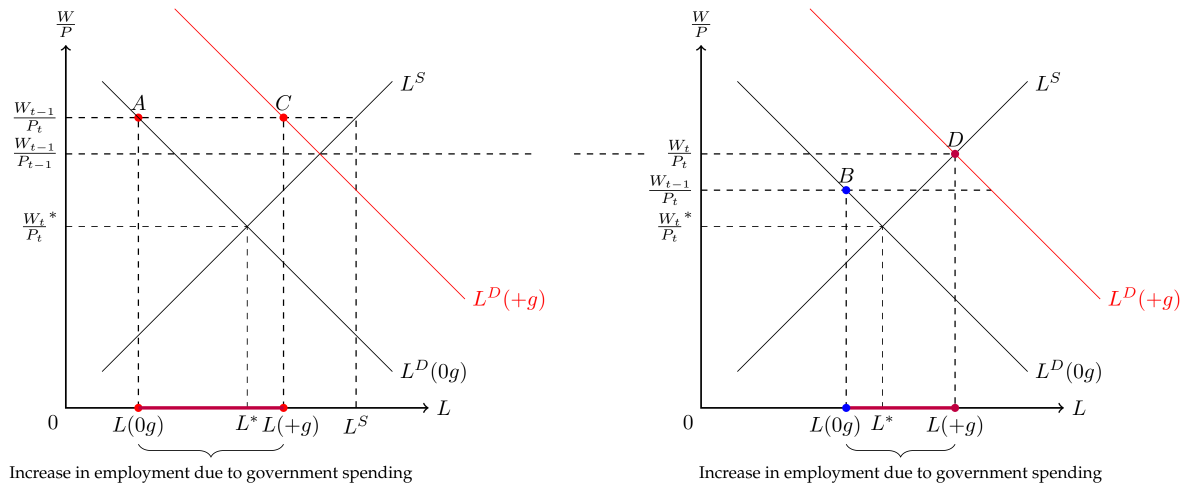
In order to understand the role of the source of the business cycle in determining the government spending multipliers, the key is to consider whether and to what extent DNWR becomes a binding constraint. From Lemma 1, we know that both a positive discount factor shock and a negative productivity shock can lead to the DNWR constraint to bind. Given the size of the contractionary shock in each recession, Lemma 2 documents the size of the lowest government spending that can restore the full employment equilibrium in a demand-driven and supply-driven recession, $c_d(\beta_H)$ and $c_s(a_L)$, respectively. As long as government spending is less than the threshold, DNWR still binds and government spending has an effectively larger output multiplier. Given the same size

[16]Note that $\frac{\partial \widehat{\pi}_t}{\partial \widehat{g}_t} = H_\pi = 0$ from the proof of Proposition 3, where DNWR binds.

[17]This statement is true under absolute DNWR. Once we allow $\gamma < 1$ in the quantitative analysis, the real interest rate rises in response to an increase in government spending.

Figure 2: An increase in government spending in a demand-driven vs. supply-driven recession, where $c_s(a_L) < g < c_d(\beta_H)$

(a) In a demand-driven recession (b) In a supply-driven recession



Notes: The figure illustrates the effect of an increase in government spending on labor in a demand-driven recession (left panel) and a supply-driven recession (right panel). Points A and B represent the labor market equilibrium in a demand-driven and supply-driven recession, respectively, without government spending. An increase in government spending shifts labor demand curve to right, resulting an equilibrium point C (left panel) and D (right panel).

productivity shock and discount factor shock, Lemma 3 shows that a government spending shock required to achieve zero unemployment is larger in a demand-driven recession than in a supply-driven recession.

Lemma 2. Assume the economy is at steady-state in period $t-1$, $\widehat{w}_{t-1} = 0$. In a demand-driven recession, if government spending is less than $\frac{\Psi}{\theta s_g}\beta_H \equiv c_d(\beta_H)$, the DNWR constraint binds, and unemployment is greater than zero. In a supply-driven recession, if government spending is less than $c_s(a_L)$, the DNWR constraint binds, and unemployment is greater than zero. Otherwise, DNWR is no longer a binding constraint, and unemployment is zero.

Proof. The proof is available in Appendix A.1.2. □

Lemma 3. Under the assumption that $|\beta_H| = |a_L|$, it can be shown that $0 < c_s(a_L) < c_d(\beta_H)$. In other words, the government spending required to ensure DNWR is no longer binding is smaller in a supply-driven recession than a demand-driven recession.

Proof. The proof is available in Appendix A.1.2. □

Based on Lemma 2 and Lemma 3, if government spending is higher than $c_s(a_L)$ but lower than $c_d(\beta_H)$, where $|\beta_H| = |a_L|$, DNWR binds in a demand-driven recession but not in a supply-driven recession. Figure 2 illustrates a rightward shift in labor demand due to an increase in government spending in both recessions described in Figure 1. Note that the size of the shift in labor demand is the same for both cases. In a demand-driven recession, this increase in government spending is not enough to achieve full employment. The new equilibrium is point C in Figure 2a, which shows that the increase in government spending can effectively raise labor without raising real wage. In contrast, this increase in labor demand due to expansionary government spending raises equilibrium real wage in a supply-driven recession, moving to equilibrium point D in Figure 2b. The increase in labor in a demand-driven recession ($L(+g) - L(0g)$ in Figure 2a) is higher than the increase in labor in a supply-driven recession ($L(+g) - L(0g)$ in Figure 2b). Therefore, an increase in output caused by an increase in government spending is larger in a demand-driven recession than in a supply-driven recession.

It is also possible to see in Figure 2 that the size and sign of government spending also matter for the size of the multiplier. If government spending is less than $c_s(a_L)$ ($c_s(a_L)$ >0), the spending multiplier in recessions would be the same in a demand-driven and supply-driven recession. Negative spending further lowers labor demand, causing DNWR to continue binding. As a result, the spending multiplier would be M_{DNWR} in a recession with contractionary government spending. The spending multipliers in an expansion can also potentially be M_{DNWR} if negative government spending is large enough to offset an increase in aggregate demand in an expansion.

Proposition 4. Under the assumption that $|\beta_H| = |a_L|$, i.e. equal sized business cycle fluctuations,

$$\begin{aligned}&\text{the spending multiplier in a demand-driven recession} \geq \\ &\text{the spending multiplier in a supply-driven recession} \geq \\ &\text{the spending multiplier in an expansion,}\end{aligned}$$

for a given size of government spending shock.

Proof. In the absence of DNWR, the multipliers are the same regardless of the state of the economy or the source of fluctuation. In the presence of DNWR ($\gamma = 1$), if government spending (g) satisfies $g < c_s(a_L)$, the DNWR constraint still binds for both recessions (Lemma 2), thus, the spending multiplier in a demand-driven recession (M^D_{DNWR}) is the same as the spending multiplier in a supply-driven recession (M^S_{DNWR}), which is greater than the spending multiplier in an expansion (M_y). If $c_s(a_L) < g < c_d(\beta_H)$, DNWR condition binds in a demand-driven recession but not in a supply-driven recession. In this case, the spending multiplier in a demand-driven recession is M^D_{DNWR} , which is higher than the spending multiplier in a supply-driven recession when DNWR is not a binding constraint, equal to the spending multiplier in an expansion, M_y. If $c_s(a_L) < c_d(\beta_H) < g$, government spending is large enough to raise nominal wages and achieve full employment, the spending multiplier would be M_y regardless of the source of fluctuation and the state of the business cycle. □

The analytical results show that government spending is more effective when the DNWR constraint binds, highlighting the main mechanisms in place. Notably, the opposing response of inflation to a preference shock versus a technology shock suggests that the degree to which the DNWR constraint binds differs across recessions led by these two different shocks. Thus, Proposition 4 states that the government spending multiplier is likely to be larger in a demand-driven recession than a supply driven recession. From the analytics, it is also clear that the relative size of the shocks to government spending determines when DNWR becomes the binding constraint and how different the multipliers are across states of the economy.

3 Quantitative measures of the state-dependent government spending multipliers

In this section, we simulate a calibrated quantitative model to generate the government spending multipliers under various scenarios, distinguishing between expansions and recessions and considering alternative sources of business cycles. Note, in order to impose an occasionally binding DNWR constraint in the model, we use the Occbin toolkit of Guerrieri and Iacoviello (2015). We relax some of the strong assumptions underlying the derivation of our analytical results including doing away with absolute downward rigidity, i.e. $\gamma = 1$.

We generalize the monetary policy rule, so that the nominal interest rate (R_t) responds to the deviations of the inflation rate and output from their own steady state, which is summarized as

$$\frac{R_t}{R} = (\frac{\pi_t}{\pi})^{\alpha_\pi}(\frac{y_t}{y})^{\alpha_y},$$

where π and y stand for the steady-state level of inflation and output, respectively.

We also assume that the discount factor, aggregate productivity, and government spending shocks follow AR(1) processes:

$$\ln(\beta_t/\beta) = \rho^\beta \ln(\beta_{t-1}/\beta) + \epsilon_t^\beta, \tag{7}$$

$$\ln(A_t/A) = \rho^A \ln(A_{t-1}/A) + \epsilon_t^A, \text{ and} \tag{8}$$

$$\ln(g_t/g) = \rho^g \ln(g_{t-1}/g) + \epsilon_t^g, \tag{9}$$

where $\epsilon_t^\beta \sim iidN(0, \sigma_\beta^2)$, $\epsilon_t^A \sim iidN(0, \sigma_A^2)$, and $\epsilon_t^g \sim iidN(0, \sigma_g^2)$.

3.1 Parameter calibration

Table 1 shows the calibration of the parameters in the model. The steady-state discount factor (β) is set to be 0.99, implying that the steady-state quarterly real interest rate is 1%. Intertemporal elasticity of substitution, σ, is 1, assuming a log utility function. We set the Frisch elasticity of labor supply ($1/(\varphi - 1)$) to be 0.5, implying φ equals to 3, which is in line with the macro estimates of Frisch elasticity from Chetty, Guren, Manoli, and Weber (2011). χ is set to ensure the steady-state level of labor to be 1. The elasticity of substitution across intermediate goods (θ) is set to be 7.67, implying the steady-state price mark-up is 15%. We set $\omega = 0.75$, implying that the firms have on average one chance to reset their price in a year. The coefficients on inflation and output of monetary policy are set at $\alpha_\pi = 1.5$ and $\alpha_y = 0.05$. We set γ, governing the degree of DNWR, as 0.98, which is the lower bound of γ from Schmitt-Grohé and Uribe (2017). This allows at most 8% decline in nominal wages annually, which is a conservative assumption on downward nominal wage rigidity.[18]

The bottom panel of Table 1 presents parameters governing shock processes. Following Fernández-Villaverde, Gordon, Guerrón-Quintana, and Rubio-Ramírez (2015), we set the persistence of the discount factor shock (ρ_β) as 0.8 and the standard deviation of the preference shock (σ_β) as 0.0025, implying the half-life of the discount factor is about 3 quarters. The persistence of the productivity shock (ρ_a) is set to be 0.96 and the standard deviation of the productivity shock (σ_a) is 0.45, following Smets and Wouters (2007). We estimate the AR(1) process using detrended real government spending data from 1960 to 2019 and set $\rho_g = 0.81$ and $\sigma_g = 0.009$.[19]

[18]Equation (2) implies that when there is an excess labor supply, $n_t^s > n_t$, the DNWR constraint binds, $W_t = \gamma W_{t-1}$. Based on the previous equation, we can calibrate using the hourly wage growth rates when we had a huge increase in unemployment during the Great Recession. Schmitt-Grohé and Uribe (2016) point out that nominal hourly wage growth rates reflect the long-run growth, while the model abstracts from it. Thus, we have to deflate the hourly wage growth rate by the long-run growth rate of the United States. The average hourly earnings quarterly growth rate (BLS series ID: CES0500000003) from 2008 to 2010 is 0.6% and the long-run average quarterly growth rate in real GDP from 1947 to 2019 is 0.8%. This implies γ equals 0.998. The recent literature sets γ higher than 0.98. For example, Rognlie and Auclert (2020) and Dupraz, Nakamura, and Steinsson (2019) use $\gamma = 1$. Barnichon, Debortoli, and Matthes (2020) allow annualized wage deflation up to 4%, implying $\gamma = 0.99$. We consider alternative degrees of price and

Table 1: Calibrated parameters

Parameters	Value	Description
β	0.99	Discount factor
σ	1	Intertemporal elasticity of substitution
φ	3	Frisch elasticity
θ	7.67	Elasticity of subtitution across goods
ω	0.75	Degree of price stickiness
α_π	1.5	Taylor coefficient
α_y	0.05	Taylor coefficient
γ	0.98	DNWR
	Shock processes	
ρ_β	0.8	Persistence of preference shock
σ_β	0.0025	Standard deviation of preference shock
ρ_a	0.95	Persistence of productivity shock
σ_a	0.45	Standard deviation of productivity shock
ρ_g	0.81	Persistence of government spending shock
σ_g	0.017	Standard deviation of government spending shock

Note: Time unit is a quarter.

3.2 Quantitative results

3.2.1 Business Cycle fluctuations under supply and demand shocks

We begin by considering the impulse responses to both contractionary and expansionary supply and demand shocks. The size of the shock is normalized to match the average output gap during the Great Recession. According to the Congressional Budget Office estimates,[20] the average output gap from 2008 to 2010 was 4%. We consider productivity and discount factor shocks to match this impact on output in a recession. This results in considering 1.7% deviations from the steady-state value of the discount factor and 2.9% deviations from the steady-state value of productivity. Both shock processes follow AR(1) process, following Equation (7) and Equation (8).[21]

Figure 3 displays impulse response in a demand-driven expansion and recession, without government spending. In response to a negative discount factor shock (shown with solid blue lines), consumers spend more in the current period leading to a demand-driven expansion. An increase in demand raises inflation and equilibrium labor. As there

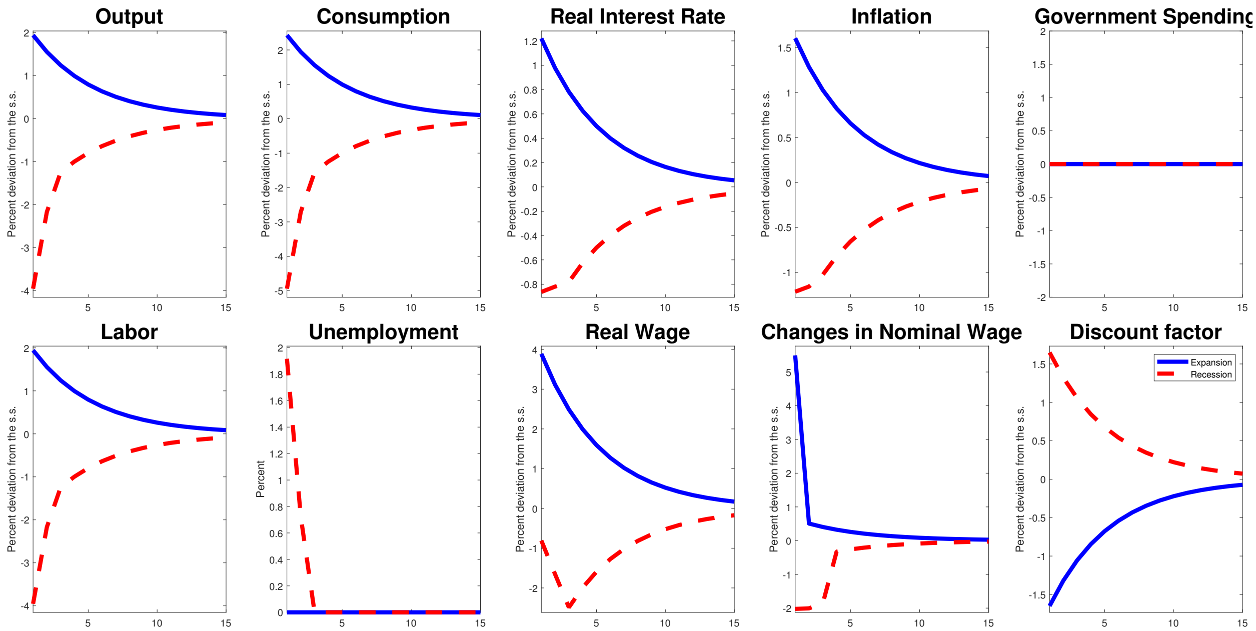
wage rigidities as robustness checks, in Appendix A.2.

[19]We applied the HP filter to real government spending data - the sum of government consumption expenditure and gross government investment minus consumption of fixed capital, deflated by the GDP deflator, following by Shen and Yang (2018).

[20]Source: https://fred.stlouisfed.org/graph/?g=f1cZ.

[21]We determine the size of the shock based on the average size of the output gap during the Great Recession, however, the slow recovery during the Great Recession was not matched in the following exercises.

Figure 3: Demand-driven business cycle



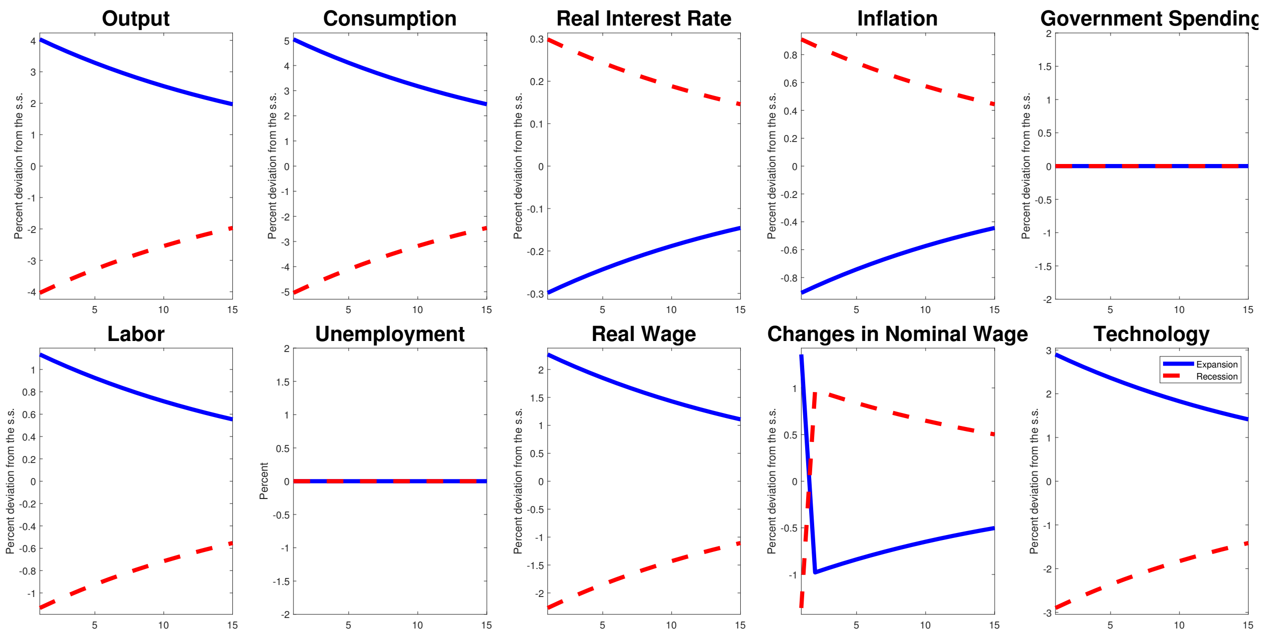
Notes: This graph shows impulse responses to a positive and a negative discount factor shock. The solid blue line corresponds to a negative discount factor shock (a demand-driven expansion), and the dashed red line represents impulse responses to a negative discount factor shock (a demand-driven recession). $\pm 1.7\%$ deviations of the discount factor shocks are imposed. All graph is drawn in terms of the percent deviations from its steady-state except the unemployment rate. The y-axis of the unemployment rate is percent.

are no frictions in adjusting nominal wages upward, the labor market always clear, and the unemployment rate is zero.

In response to a positive discount factor shock (shown with dashed red lines in Figure 3), consumers postpone current consumption, which causes a recession. As labor demand decreases, there is downward pressure on wages. Although real wage goes up more than 4% in an expansion, the downward adjustment of real wage is about 1% at the beginning of the recession due to deflation and the binding of the DNWR constraint. The DNWR constraint allows at most 2% downward adjustment of real wage. At the same time, there is deflation that drives the real wages upward. The comovement of inflation and output, shown in Proposition 1, exacerbates the labor market outcome and raises unemployment. Overall, the binding DNWR constraint generates an asymmetric business cycle.

Figure 4 shows a supply-driven business cycle. As shown in Proposition 1, inflation and output move in the opposite directions in a supply-driven recession. In a recession (dashed red lines), the marginal product of labor goes down, and firms hire less labor. Accordingly, nominal wage goes down about 1.5%. As we allow the downward adjustment of nominal wage up to 2%, the DNWR constraint does not bind. Consequently, the labor market clears, and the unemployment rate is zero. Unlike the demand-driven reces-

Figure 4: Supply-driven business cycle



Notes: This graph displays impulse responses to a positive and a negative productivity shock. The solid blue lines correspond to a positive productivity shock (a supply-driven expansion). The dashed red lines represent impulse responses to a negative productivity shock(a supply-driven recession). $\pm 2.9\%$ deviations of the technology shocks are imposed. All graph is drawn in terms of the percent deviations from its steady-state except the unemployment rate. The y-axis of the unemployment rate is percent.

sion, the downward adjustment of real wage is greater than that of nominal wage in the supply-driven recession due to inflation. This is also highlighted in the analytical section. The supply-driven business cycle is fully symmetric as DNWR does not bind.[22]

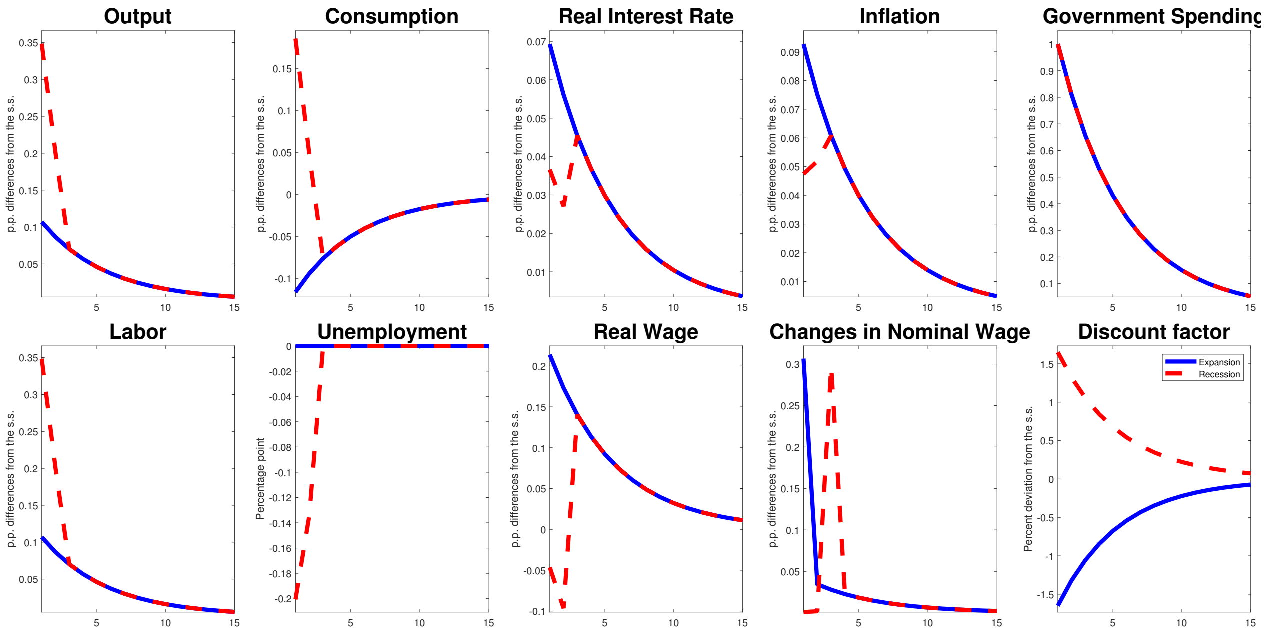
3.2.2 State-dependent effects of government spending

Now let us consider the effect of government spending relying upon the state of the economy and the source of fluctuation. Figure 5 shows the differences of impulse responses with and without government spending in a demand-driven expansion (shown with the solid blue lines) and in a demand-driven recession (shown with the dashed red lines). We consider a 1% deviation of government spending from its steady state.

Regardless of the state of the economy, an increase in government spending raises labor and output. In a recession, an increase in government spending does not raise nominal wages immediately since DNWR is a binding constraint. While nominal wage is fixed in a recession, inflation increases due to an increase in demand. As a result, real

[22]When we consider King, Plosser, and Rebelo (1988) preferences in Section 3.3.3, we find asymmetric business cycles in response to a supply shock as well. Once we allow for a wealth effect on labor supply in response to a technology shock, nominal wages fall more than in our baseline case and are bound below by DNWR in a supply-driven recession as well.

Figure 5: Effects of government spending shock for demand-driven business cycle

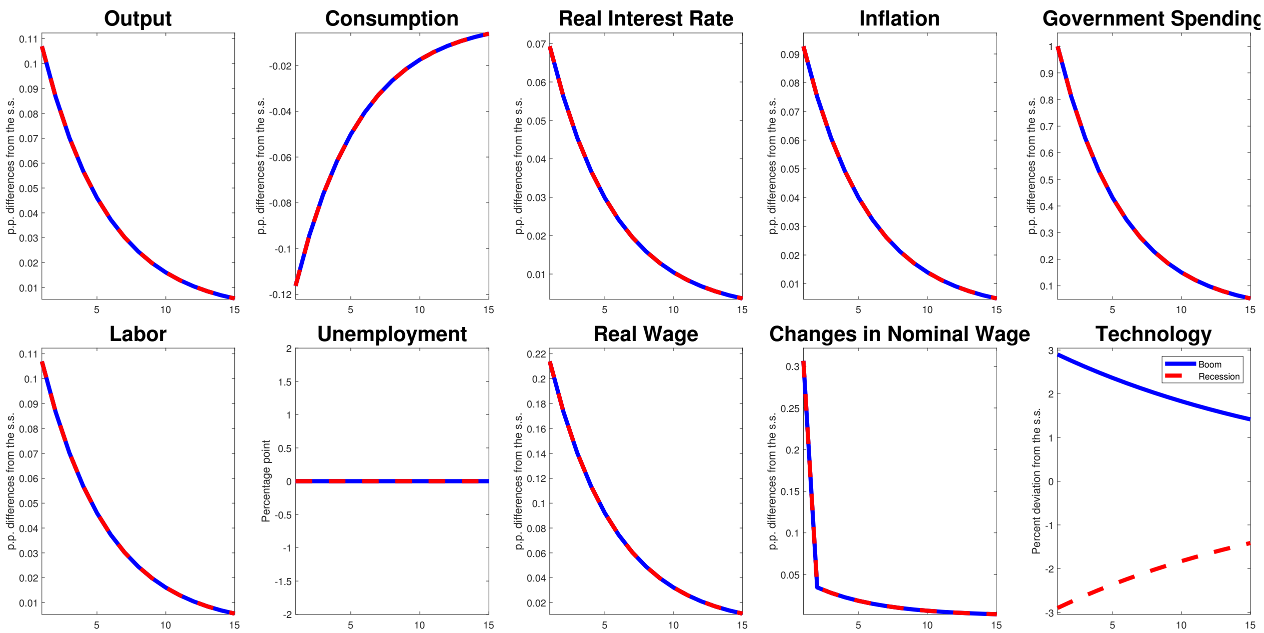


Notes: This graph displays the differences of impulse responses with government spending compared to the one without government spending in a demand-driven expansion (solid blue lines) and a demand-driven recession (dashed red lines). $\pm 1.7\%$ deviations of the discount factor shocks are imposed. All graph is drawn in terms of the percentage points differences from its steady-state except the unemployment rate and the discount factor. The y-axis of the unemployment rate is the percentage point.

wage goes down, stimulating the labor market. In contrast, in an expansion, real wage increases in response to an increase in demand. This increase in real wage dilutes the effect of the increase in government spending. Therefore, an increase in labor due to expansionary government spending is smaller in a boom compared to a bust. Similarly, the increase in government spending lowers the unemployment rate in a recession when DNWR is the binding constraint, while it does not affect unemployment in an expansion. These results in a demand-driven business cycle are consistent with Shen and Yang (2018).

Furthermore, the increase in inflation is weaker in a demand-driven recession than in a demand-driven expansion. An increase in government spending in a recession lowers real wage and thus marginal cost. This weakens the response of inflation, caused by an increase in demand, leading to a smaller response of nominal interest rate according to Taylor rule. Consequently, there is a smaller increase in the real interest rate in a recession, limiting the crowding-out effect on private consumption. To summarize, an increase in government spending is more effective in a demand-driven recession when the DNWR constraint binds because 1) it can increase the quantity of labor without raising nominal wage, and 2) it has less inflationary pressure leading to a smaller rise in real interest rates.

Figure 6: Effects of government spending shock for supply-driven business cycle



Notes: This graph displays the differences of impulse responses with government spending compared to the one without government spending in a supply-driven expansion (solid blue line) and a supply-driven recession (dashed red line). $\pm 2.9\%$ deviations of the technology shocks are imposed. All graph is drawn in terms of the percentage points differences from its steady-state except the unemployment rate and the discount factor. The y-axis of the unemployment rate is the percentage point.

This result is consistent with Proposition 3 from Section 2.3 that government spending is more effective when DNWR is the binding constraint. In conclusion, government spending is state-dependent in a demand-driven business cycle and much larger in a recession period than in an expansion.

Figure 6 displays the differences in impulse response in a supply-driven business cycle with and without government spending. Since the DNWR constraint does not bind in a supply-driven recession (refer to Figure 4), the responses of the macroeconomic variables are the same regardless of the state of the economy. This result is consistent with Proposition 2 that the government spending multipliers are acyclical in a supply-driven business cycle when the DNWR constraint is not a binding constraint. This also shows that if instead of a recession driven by demand shocks, we consider the same sized recession driven by supply shocks, the main result of Shen and Yang (2018) of state dependent government spending multipliers disappears. We get the same multiplier in a recession and expansion, illustrating the importance of the source of recession in the size of the multiplier.[23]

[23]When we consider KPR preferences in Section3.3.3, the multiplier in a supply-driven recession is smaller than a demand-driven recession but larger than in an expansion (shown in Table 3), since DNWR also binds in a supply driven recession.

Table 2: Cumulative output and consumption multipliers by the source of fluctuation

		Demand-driven business cycle				Supply-driven business cycle		
		Impact	4 quarters	20 quarters		Impact	4 quarters	20 quarters
Output Multiplier	Expansion	0.535	0.535	0.535	Expansion	0.535	0.535	0.535
	Recession	1.742	1.129	0.879	Recession	0.535	0.535	0.535
Consumption Multiplier	Expansion	-0.465	-0.465	-0.465	Expansion	-0.465	-0.465	-0.465
	Recession	0.742	0.129	-0.121	Recession	-0.465	-0.465	-0.465

Notes. This table reports the cumulative output and consumption multipliers in an expansion and a recession depending on the source of fluctuation. The cumulative output and consumption multipliers are calculated as $\Sigma_{i=0}^{i=k-1} \frac{\Delta y_{t+i}}{(1+r_{t+i})} \big/ \Sigma_{i=0}^{i=k-1} \frac{\Delta g_{t+i}}{(1+r_{t+i})}$ and $\Sigma_{i=0}^{i=k-1} \frac{\Delta c_{t+i}}{(1+r_{t+i})} \big/ \Sigma_{i=0}^{i=k-1} \frac{\Delta g_{t+i}}{(1+r_{t+i})}$, respectively, where Δ denotes the level differences of each variable with and without government spending and r_t is the real interest rate.

Table 2 summarizes the cumulative output and consumption multipliers depending on the state of the economy and the source of fluctuation. The multipliers are state-dependent (countercyclical) in the demand-driven business cycle taking a value above 1 (1.7 on impact) in a recession and 0.5 in an expansion. This larger multiplier in the recession is driven by a positive multiplier for consumption, at least in the short-run, while the consumption multiplier is negative during an expansion. On the other hand, the multipliers are acyclical in the supply-driven business cycle. The multipliers are higher in the demand-driven recession when the DNWR constraint binds as shown in Proposition 4. Nominal wage goes up in an expansion, and the drop in nominal wage in a supply-driven recession does not trigger the binding DNWR constraint in the baseline specification, whereas DNWR binds in a demand-driven recession. As nominal wage gradually adjusts in a demand-driven recession, the difference of the cumulative multipliers in a demand-driven recession and an expansion dissipates over time. Thus, both the underlying economic states and the source of fluctuations matter in determining the size of the spending multipliers.

3.3 Robustness checks and additional explorations

Table 3: Cumulative output and consumption multipliers by the source of fluctuation

		Demand-driven business cycle				Supply-driven business cycle		
		Impact	4 quarters	20 quarters		Impact	4 quarters	20 quarters
A. Mild business cycle (Half size of the baseline shock)								
Output	Expansion	0.535	0.535	0.535	Expansion	0.535	0.535	0.535
Multiplier	Recession	0.819	0.630	0.590	Recession	0.535	0.535	0.535
Consumption	Expansion	-0.465	-0.465	-0.465	Expansion	-0.465	-0.465	-0.465
Multiplier	Recession	-0.181	-0.370	-0.410	Recession	-0.465	-0.465	-0.465
B. Severe business cycle (One and a half size of the baseline shock)								
Output	Expansion	0.535	0.535	0.535	Expansion	0.535	0.535	0.535
Multiplier	Recession	2.445	1.867	1.306	Recession	0.560	0.543	0.540
Consumption	Expansion	-0.465	-0.465	-0.465	Expansion	-0.465	-0.465	-0.465
Multiplier	Recession	1.445	0.867	0.306	Recession	-0.440	-0.457	-0.460
C. Large government spending shock (10% deviation from the steady-state)								
Output	Expansion	0.535	0.535	0.535	Expansion	0.535	0.535	0.535
Multiplier	Recession	1.459	0.948	0.774	Recession	0.535	0.535	0.535
Conumption	Expansion	-0.465	-0.465	-0.465	Expansion	-0.465	-0.465	-0.465
Multiplier	Recession	0.459	-0.052	-0.226	Recession	-0.465	-0.465	-0.465
D. Negative government spending shock (Negative 1% deviation from the steady-state)								
Output	Expansion	0.535	0.535	0.535	Expansion	0.535	0.535	0.535
Multiplier	Recession	2.051	1.428	1.052	Recession	0.535	0.535	0.535
Conumption	Expansion	-0.465	-0.465	-0.465	Expansion	-0.465	-0.465	-0.465
Multiplier	Recession	1.051	0.428	0.052	Recession	-0.465	-0.465	-0.465
E. KPR preference								
Output	Expansion	0.485	0.485	0.485	Expansion	0.485	0.485	0.485
Multiplier	Recession	0.668	0.621	0.564	Recession	0.528	0.500	0.494
Consumption	Expansion	-0.515	-0.515	-0.515	Expansion	-0.515	-0.515	-0.515
Multiplier	Recession	-0.332	-0.379	-0.436	Recession	-0.472	-0.500	-0.506

Notes. This table reports the cumulative output and consumption multipliers in an expansion and a recession depending on the source of fluctuation. The cumulative output and consumption multipliers are calculated as $\Sigma_{i=0}^{i=k-1} \frac{\Delta y_{t+i}}{(1+r_{t+i})} \big/ \Sigma_{i=0}^{i=k-1} \frac{\Delta g_{t+i}}{(1+r_{t+i})}$ and $\Sigma_{i=0}^{i=k-1} \frac{\Delta c_{t+i}}{(1+r_{t+i})} \big/ \Sigma_{i=0}^{i=k-1} \frac{\Delta g_{t+i}}{(1+r_{t+i})}$, respectively, where Δ denotes the level differences of each variable with and without government spending and r_t is the real interest rate.

3.3.1 Size of business cycle fluctuations

The magnitude of the spending multipliers also depends on the size of underlying fluctuations. Panel A and B of Table 3 report the cumulative output and consumption multipliers for mild and severe business cycles, respectively. The multipliers in a demand-driven recession rise with the size of the discount factor shock. In our baseline experiment, the size of the recession is calibrated to match the depth of the Great Recession. If we consider a milder recession, generated by half the size of the baseline discount factor, then the impact output multiplier is 0.82, i.e. less than one even in a demand-driven recession. In a severe demand-driven recession, the unemployment rate is high. Under these circumstances, an additional increase in demand greatly raises output leading to a significantly larger output and consumption multiplier. Similarly, the spending multiplier is higher in a severe supply-driven recession since DNWR starts to bind. However, the extent of binding DNWR constraint in a severe supply recession is not as large as in a severe demand recession. As a result, the multiplier in a severe supply recession is much lower than the one in a severe demand recession.

3.3.2 Size and sign of government spending

The size and the sign of government spending also play a role in determining the magnitude of the spending multipliers. A large increase in government spending greatly reduces the labor market distortions. This reduces the overall spending multiplier in a demand-driven recession (See Panel C of Table 3). The multiplier for a ten times larger shock to government spending yields a multiplier of 1.46 on impact in a demand-driven recession, compared to 1.74 for a one percent increase in our baseline case. As marginal increases in government spending reduce the labor market distortion to a smaller extent, it becomes less effective in leading to a sizable increase in output. However, the size of government spending does not affect the spending multiplier in a supply-driven business cycle since DNWR does not bind.

A negative government spending in a demand-driven recession further exacerbates the labor market, raising the spending multiplier to above 2 (See Panel D of Table 3). This result is partly consistent with empirical findings from Barnichon, Debortoli, and Matthes (2020) that suggest the spending multiplier for a negative shock to government spending is larger in a slack state than the multiplier for a positive shock. Once again, since the DNWR does not bind in a supply-driven recession, the sign of government spending intervention does not affect the size of the multipliers in a high inflation slack period. These results suggest that fiscal austerity is particularly harmful in a demand-driven recession.

3.3.3 Robustness to alternative preferences

Our baseline model considers GHH (Greenwood, Hercowitz, and Huffman (1988)) preferences which do not allow a wealth effect on labor supply. We relax this assumption and allow for wealth effects on labor supply by introducing KPR (King, Plosser, and Rebelo (1988)) preferences commonly used in the literature. In particular, the preferences take the following form,

$$U(c_t, n_t) = \frac{[c_t(1 - \chi n_t^{\varphi})]^{1-\sigma}}{1-\sigma},$$

where we calibrate φ to ensure the same degree of Frisch elasticity of labor supply as in our baseline model.

As panel E of Table 3 shows, the multipliers under these preferences are smaller across the board relative to GHH preferences.[24] This is because an increase in government spending under KPR preferences leads to negative wealth effects on the labor supply, as agents internalize higher taxes now or in the future. Consequently, this leads to a fall or a smaller rise in wages, and thus consumption is crowded out to a larger degree. Note also, that the multiplier in a demand-driven recession is larger than in an expansion (0.67 in a recession and 0.49 in an expansion under KPR preferences), but is much smaller in magnitude relative to under GHH preferences, (1.74 in a recession and 0.54 in an expansion under GHH preferences). This is because the labor supply curve shifts to the right, and overall weakens the effects of increased spending in reducing unemployment. Under these preferences, DNWR binds in a supply-driven recession as well, leading to a larger output multiplier in a recession relative to an expansion.[25] However, the difference in the multiplier across states is small and the multiplier in a supply-driven recession is smaller than the multiplier in a demand-driven recession (0.53 versus 0.67, respectively). The intuition follows from Proposition 4 shown in Section 2.3.

3.3.4 Robustness to trend inflation

Given that differences in real wage response are at the heart of the state-dependent multipliers, rigidities affecting both wages and prices potentially play an important role.[26] While demand and supply shocks generate deviations from steady-state inflation in opposite direction, we also consider the importance of the level of steady-state inflation. Table 4 shows the cumulative output and consumption multipliers when we consider a 2% annual steady-state inflation. The main results hold qualitatively: notably that the output and consumption multipliers are higher in a demand-driven recession compared to an expansion for both GHH and KPR preferences. For KPR preferences, shown in the bottom panel, similar to the zero steady-state inflation case, the multiplier in a supply-

[24] Under these preferences, we need to adjust the size of both the discount factor and productivity shock in order to generate the same size recession state.

[25] DNWR is more likely to bind in this case in response to a technology shock, since wages have a relatively larger response and labor has a smaller response with KPR preferences as the wealth effects from a technology shock shift the labor supply curve, an effect missing with GHH preferences.

[26] We consider the sensitivity of our results to alternative degrees of DNWR and price stickiness in Appendix A.2.

Table 4: Cumulative output and consumption multipliers with nonzero steady-state inflation

		Demand-driven business cycle				Supply-driven business cycle		
		Impact	4 quarters	20 quarters		Impact	4 quarters	20 quarters
A. 2% steady-state annual inflation with GHH preference								
Output Multiplier	Expansion	0.345	0.314	0.236	Expansion	0.345	0.314	0.236
	Recession	1.067	0.653	0.439	Recession	0.345	0.314	0.236
Consumption Multiplier	Expansion	-0.655	-0.686	-0.764	Expansion	-0.655	-0.686	-0.764
	Recession	0.067	-0.347	-0.561	Recession	-0.655	-0.686	-0.764
A. 2% steady-state annual inflation with KPR preference								
Output Multiplier	Expansion	0.477	0.467	0.446	Expansion	0.477	0.467	0.446
	Recession	0.646	0.598	0.529	Recession	0.512	0.480	0.455
Consumption Multiplier	Expansion	-0.523	-0.533	-0.554	Expansion	-0.523	-0.533	-0.554
	Recession	-0.354	-0.402	-0.471	Recession	-0.488	-0.520	-0.545

Notes. This table reports the cumulative output and consumption multipliers in an expansion and a recession with 2% steady-state annual inflation under GHH and KPR preferences.. The cumulative output and consumption multipliers are calculated as $\Sigma_{i=0}^{i=k-1}\frac{\Delta y_{t+i}}{(1+r_{t+i})}\big/\Sigma_{i=0}^{i=k-1}\frac{\Delta g_{t+i}}{(1+r_{t+i})}$ and $\Sigma_{i=0}^{i=k-1}\frac{\Delta c_{t+i}}{(1+r_{t+i})}\big/\Sigma_{i=0}^{i=k-1}\frac{\Delta g_{t+i}}{(1+r_{t+i})}$, respectively, where Δ denotes the level differences of each variable with and without government spending and r_t is the real interest rate.

driven recession, while larger than in an expansion, is smaller than in a demand-driven recession.

The positive steady-state inflation multipliers are overall smaller than the zero steady-state inflation multipliers. This difference is because non-zero steady-state inflation in a New Keynesian model leads to a rise in price dispersion and a loss in labor efficiency in response to exogenous shocks.[27] With GHH preferences, the increase in inefficient price dispersion due to an increase in government spending limits the expansionary effects on output significantly. As a result, the government spending multipliers are much smaller with a 2% steady-state annual inflation rate. However, with KPR preference, labor supply also responds to government spending shocks which partially offsets the impact on aggregate demand due to a change in price dispersion. Consequently, there are smaller differences in the size of the multipliers across zero and non-zero steady-state inflation.

[27] See Ascari (2004) for a more detailed discussion.

4 Time series empirical evidence

4.1 Econometric Methodology

As we establish in the previous section, the government spending multipliers in a recession with the binding DNWR constraint can differ based on the inflation response, relative to steady state, which is different across demand and supply-driven recessions. In order to investigate empirically whether the government spending multipliers are state-dependent and if the nature of recession matters, we exploit the rich long time series data for the US, where there is a large variation in government spending, the unemployment rate and also periods of high and low inflation. We employ the one-step IV estimation procedure for the fiscal multipliers as introduced in Ramey and Zubairy (2018), and estimate state-dependent local projections a la Jordà (2005). In departure from their analysis, we distinguish not only between low and high unemployment periods, but also consider the interaction between unemployment and inflation. We separately consider high unemployment periods accompanied with low inflation or more precisely inflation below trend inflation, which can be thought of as an analog of the demand-driven recession in our model. Similarly, we consider periods with high unemployment and high inflation, i.e. inflation above trend inflation, which corresponds to a supply-driven recession in our theoretical framework.

We consider the following state-dependent local projection model,

$$\sum_{j=0}^{h} y_{t+j} \quad = \quad \sum_{d} \mathbb{I}(\text{State } d) \left[\gamma_{d,h} + \phi_{d,h}(L) z_{t-1} + m_{d,h} \sum_{j=0}^{h} g_{t+j} \right] + \omega_{t+h},$$

where y_t is real GDP and g_t is real government spending, both normalized by trend GDP.[28][29] The normalization and consideration of cumulative GDP and government spending variables ensures that the coefficient m_h can be interpreted as the cumulative

[28]Trend or potential GDP is constructed by using a sixth-order polynomial. This normalization for GDP and government spending ensures we do not have to use the average share of government spending to GDP to convert government spending into GDP units and thus to get the multipliers. Ramey and Zubairy (2018) show that this approach can bias the multipliers, particularly in samples where there is large variation in spending as a share of GDP.

[29]Based on Figure 5 and 6, another way to validate the model predictions is to estimate the differential responses of aggregate wages in response to government spending shock depending on the source of the business cycle. However, this is hard to implement with aggregate wages. Firstly, there is no such long time series for wages available. Aggregate wages also suffer from composition bias (Solon, Barsky, and Parker (1994)), as there are changes in the composition of workers in recessions and aggregate wages are thus constructed with a relatively larger weight on highly-paid workers. This overall makes it harder to differentiate between the responses of aggregate wages in response to macroeconomic shocks.

government spending multiplier at horizon h in a given state. In our baseline specification we consider an indicator function for the *pre-existing* state of the economy when the shock hits, which correspond to $\mathbb{I}(L(u_{t-1}))$, the state where lagged unemployment is low, $\mathbb{I}(H(u_{t-1})) \times \mathbb{I}(L(\pi_{t-1}))$, periods of lagged high unemployment and low inflation and $\mathbb{I}(H(u_{t-1})) \times \mathbb{I}(H(\pi_{t-1}))$, which correspond to periods of lagged high unemployment and high inflation. We use $\mathbb{I}_{t-1} \times shock_t$ as the instruments for the respective interaction of cumulative government spending with the state indicator, where in our baseline specification the shock we consider is the military news variable from Ramey and Zubairy (2018). Since this LP-IV approach allows us to consider multiple instruments, we also consider the case with both military news and identification based on Blanchard and Perotti (2002).

Our data set constitutes of quarterly data for the U.S. spanning 1889Q1-2017Q4. We define inflation as year-over-year growth of the GDP deflator, and use data for GDP, unemployment rate, government spending and GDP deflator from Ramey and Zubairy (2018). Our baseline measure of narrative military news variables also comes from Ramey and Zubairy (2018). In order to define states, we consider high or low unemployment periods where the unemployment rate is above or below the threshold of 6.5 %, respectively, as considered by Ramey and Zubairy (2018). We further consider that high and low inflation periods are defined as above or below a HP filtered trend with $\lambda = 1600$. A positive deviation from the trend is considered as periods of high inflation.[30] Using this distinction in the inflation rates to distinguish between the type of recession implies that the Great Depression, for the most part, and the Great Recession were demand-driven recessions. On the other hand, recessions in the mid 1970s and early 1980s start off as supply-driven recessions before negative demand forces take over.[31]

4.2 Estimation Results

Table 5 shows our baseline results, where we consider military news variable to identify the government spending shocks, for the estimated state-dependent multipliers. The

[30] We conduct additional robustness checks with alternative thresholds for both inflation and unemployment rate in Appendix A.3. Table A.2 uses time-varying thresholds for both the unemployment rate and inflation. Table A.3 and A.4 estimate the multipliers using time-invariant thresholds for both unemployment and inflation with military new shocks and both news and Blanchard-Perotti (2002) shocks as instruments, respectively.

[31] The classification of these different states along with data on military news, unemployment rate and inflation are shown in Figure A.4 in Appendix A.3. The classifications of the recessions, particularly in the 1970s and 1980s are consistent with ones presented in Blanchard and Quah (1989). For example, the early 1980 recession start with a supply-driven forces as the 1978-1979 Iranian revolution and 1980-1981 Iran-Iraq war led to a cut in oil production, resulting in high inflation. The Fed tightening monetary policy resulted in a demand-driven recession for the latter part of the early 1980 recession.

Table 5: State-dependent fiscal multipliers for output: military news shocks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		2-year integral output				4-year integral output		
Σg_t	0.6637***				0.7134***			
	(0.0671)				(0.0436)			
$\Sigma g_t \times \mathbb{I}(L(u_{t-1}))$		0.5949***		0.5949***		0.6683***		0.6683***
		(0.0905)		(0.0907)		(0.1236)		(0.1240)
$\Sigma g_t \times \mathbb{I}(H(u_{t-1}))$		0.6029***				0.6820***		
		(0.0888)				(0.0536)		
$\Sigma g_t \times \mathbb{I}(L(\pi_{t-1}))$			0.7813***				0.6878***	
			(0.1115)				(0.0791)	
$\Sigma g_t \times \mathbb{I}(H(\pi_{t-1}))$			0.5760***				0.7252***	
			(0.0353)				(0.0450)	
$\Sigma g_t \times \mathbb{I}(H(u_{t-1}))\mathbb{I}(L(\pi_{t-1}))$				1.2635***				0.8159***
				(0.2715)				(0.0759)
$\Sigma g_t \times \mathbb{I}(H(u_{t-1}))\mathbb{I}(H(\pi_{t-1}))$				0.2297***				0.5835***
				(0.0738)				(0.0570)
P-value from the test								
$\mathbb{I}(L(u_{t-1})) = \mathbb{I}(H(u_{t-1}))$		0.95				0.92		
$\mathbb{I}(L(\pi_{t-1})) = \mathbb{I}(H(\pi_{t-1}))$			0.10				0.67	
$\mathbb{I}(L(u_{t-1})) = \mathbb{I}(H(u_{t-1}))\mathbb{I}(L(\pi_{t-1}))$				0.03				0.34
$\mathbb{I}(L(u_{t-1})) = \mathbb{I}(H(u_{t-1}))\mathbb{I}(H(\pi_{t-1}))$				0.00				0.56
$\mathbb{I}(H(u_{t-1}))\mathbb{I}(L(\pi_{t-1})) = \mathbb{I}(H(u_{t-1}))\mathbb{I}(H(\pi_{t-1}))$				0.00				0.01
First-stage F statistics								
Linear	19.38				11.22			
$\mathbb{I}(L(u_{t-1}))$		8.44		8.23		10.85		10.56
$\mathbb{I}(H(u_{t-1}))$		403.28				130.20		
$\mathbb{I}(L(\pi_{t-1}))$			6.17				4.40	
$\mathbb{I}(H(\pi_{t-1}))$			131.60				38.59	
$\mathbb{I}(H(u_{t-1}))\mathbb{I}(L(\pi_{t-1}))$				139.80				90.16
$\mathbb{I}(H(u_{t-1}))\mathbb{I}(H(\pi_{t-1}))$				619.63				722.32
Observations	493	493	493	493	485	485	485	485

Notes: The top panel panel reports the 2 and 4 year cumulative multiplier along with associated standard errors below. The second panel shows p-values testing whether the multipliers are statistically significantly different across states. The last panel shows the first-stage F statistics for military news as an instrument at 2 and 4 year horizons for the given state. * p<0.10, ** p<0.05, ***p<0.01. Standard errors in parentheses.

multipliers are defined as the cumulative multipliers, which account for the cumulative dynamics of output and government spending, as advocated for in Mountford and Uhlig (2009). The linear and the two-state multipliers based on the level of unemployment rate replicate the findings of Ramey and Zubairy (2018). Similarly, the multipliers are not statistically different from each other depending on the level of inflation. Notably, if we do not condition on the nature of a recession, the spending multipliers are not estimated to be state-dependent and are not statistically different across periods of high and low unemployment or inflation. Once we consider three states, we find the 2 year integral multiplier of 0.6 in the low unemployment state, which is close to the linear multiplier. At the 2 year horizon, the multiplier in the high unemployment state significantly dif-

Table 6: State-dependent fiscal multipliers for output: both military news and Blanchard-Perotti (2002) as instruments

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		2-year integral output				4-year integral output		
Σg_t	0.4175***				0.5639***			
	(0.0979)				(0.0837)			
$\Sigma g_t \times \mathbb{I}(L(u_{t-1}))$		0.3343***				0.3873***		
		(0.1095)				(0.1080)		
$\Sigma g_t \times \mathbb{I}(H(u_{t-1}))$		0.6185***				0.6809***		
		(0.0921)				(0.0536)		
$\Sigma g_t \times \mathbb{I}(L(\pi_{t-1}))$			0.4728***				0.4914***	
			(0.0896)				(0.0969)	
$\Sigma g_t \times \mathbb{I}(H(\pi_{t-1}))$			0.4802***				0.6715***	
			(0.0687)				(0.0665)	
$\Sigma g_t \times \mathbb{I}(L(u_{t-1}))\mathbb{I}(L(\pi_{t-1}))$				0.4305***				0.3023
				(0.1473)				(0.1950)
$\Sigma g_t \times \mathbb{I}(L(u_{t-1}))\mathbb{I}(H(\pi_{t-1}))$				0.4191***				0.5510***
				(0.0735)				(0.1174)
$\Sigma g_t \times \mathbb{I}(H(u_{t-1}))\mathbb{I}(L(\pi_{t-1}))$				0.9186***				0.8082***
				(0.2296)				(0.0684)
$\Sigma g_t \times \mathbb{I}(H(u_{t-1}))\mathbb{I}(H(\pi_{t-1}))$				0.5647***				0.8018***
				(0.1975)				(0.1285)
P-value from the test								
$\mathbb{I}(L(u_{t-1})) = \mathbb{I}(H(u_{t-1}))$		0.10				0.02		
$\mathbb{I}(L(\pi_{t-1})) = \mathbb{I}(H(\pi_{t-1}))$			0.94				0.09	
$\mathbb{I}(L(u_{t-1}))\mathbb{I}(L(\pi_{t-1})) = \mathbb{I}(L(u_{t-1}))\mathbb{I}(H(\pi_{t-1}))$				0.93				0.21
$\mathbb{I}(L(u_{t-1}))\mathbb{I}(L(\pi_{t-1})) = \mathbb{I}(H(u_{t-1}))\mathbb{I}(L(\pi_{t-1}))$				0.60				0.06
$\mathbb{I}(L(u_{t-1}))\mathbb{I}(H(\pi_{t-1})) = \mathbb{I}(H(u_{t-1}))\mathbb{I}(L(\pi_{t-1}))$				0.05				0.06
$\mathbb{I}(H(u_{t-1}))\mathbb{I}(L(\pi_{t-1})) = \mathbb{I}(H(u_{t-1}))\mathbb{I}(H(\pi_{t-1}))$				0.22				0.96
First-stage F statistics								
Linear	64.59				28.40			
$\mathbb{I}(L(u_{t-1}))$		79.26				24.60		
$\mathbb{I}(H(u_{t-1}))$		280.33				72.29		
$\mathbb{I}(L(\pi_{t-1}))$			72.91				42.70	
$\mathbb{I}(H(\pi_{t-1}))$			103.28				17.28	
$\mathbb{I}(L(u_{t-1}))\mathbb{I}(L(\pi_{t-1}))$				136.29				15.62
$\mathbb{I}(L(u_{t-1}))\mathbb{I}(H(\pi_{t-1}))$				48.97				18.36
$\mathbb{I}(H(u_{t-1}))\mathbb{I}(L(\pi_{t-1}))$				118.30				78.34
$\mathbb{I}(H(u_{t-1}))\mathbb{I}(H(\pi_{t-1}))$				405.39				404.44
Observations	493	493	493	493	485	485	485	485

Notes: The top panel panel reports the 2 and 4 year cumulative multiplier along with associated standard errors below. The second panel shows p-values testing whether the multipliers are statistically significantly different across states. The last panel shows the first-stage F statistics for military news and Blanchard and Perotti (2002) shocks jointly as instruments at 2 and 4 year horizons for the given state. * p<0.10, ** p<0.05, ***p<0.01. Standard errors in parentheses.

fers based on inflation; being 1.3 in the low inflation state and 0.2 in the high inflation. The multiplier in the high unemployment/ low inflation state is statistically significantly larger than the multiplier in the low unemployment state. At the 4 year horizon, the low unemployment multiplier is close to the linear multiplier, at close to 0.7. Again, the multipliers are statistically significantly different when the unemployment rate is high, based on the state of inflation. They are estimated to be about 0.8 and 0.6 across the low and high inflation states, respectively.[32] This provides evidence consistent with our theoretical findings: the government spending multiplier is significantly larger in a demand-driven recession than a supply-driven recession.[33]

The primary reason behind conducting a three state analysis and not distinguishing between the inflation rate across the non-slack states is the extremely low instrumental relevance of military news for the low unemployment and low inflation state. As shown in the bottom panel of Table 5, the instrumental relevance of military news is still rather small in the low unemployment state overall. On the other hand, the alternative leading identification scheme of Blanchard and Perotti (2002), based on assuming that government spending does not respond to contemporaneous output and macroeconomic variables in the same quarter, has very low instrumental relevance in the high unemployment state.[34] In order to deal with these instrumental relevance issues, we also conduct the same analysis using both military news and Blanchard and Perotti (2002) shocks as joint instruments, shown in Table 6. In this case, the multipliers are overall estimated to be smaller, but we do not run into any instrumental relevance issues across the various states and horizons. We first replicate the findings of Ramey and Zubairy (2018) that there

[32]The table reports 2 and 4 year horizons multipliers only, but Figure A.5 in Appendix A.3 shows the multipliers and corresponding standard error bands over the entire 5 year horizon.

[33]The empirical estimates for the average multiplier in a demand-driven recession are close to 1 and smaller than the multipliers from the quantitative model. This is essential because we simulate a deep recession in a model and as further explorations of the quantitative model reveal, the multiplier in a demand-driven recession can even be less than one in a mild recession. Table 5 also reports that the multiplier in a supply-driven recession (periods with high unemployment accompanied with high inflation) is smaller than the multiplier in an expansion. At first glance, it seems contradictory to Proposition 4, but those results are derived under the assumption of the equal sized business cycle for a given size and sign of government spending. However, large government spending in a mild supply-driven recession can generate a relatively smaller multiplier, or a large negative government spending in an expansion can lead to a larger multiplier.

We also verify that the overall sign of government spending shocks does not necessarily drive our state-dependent government spending multipliers. Barnichon, Debortoli, and Matthes (2020) find larger multipliers in periods of economic slack as a result of contractionary government spending shocks. The frequency of contractionary military spending news shock is 48% in a demand-driven recession and 64% in a supply-driven recession in our sample. Despite there being larger number of contractionary government spending shocks in a supply-driven recession, we find smaller multipliers in this state.

[34]Ramey and Zubairy (2018) have already shown that beyond the impact, the instrumental relevance of Blanchard and Perotti shocks become smaller at longer horizons of 2 and 4 years out, based on the underlying identification assumption.

is evidence of a larger multiplier in periods of slack versus no slack, but the multipliers are always below 1. We also document that the multipliers are not a function of the level of inflation relative to trend. Column (4) reports that the multipliers in expansions, regardless of inflation, are similar to each other. While it is not possible to completely rule out other explanations for state-dependence of multipliers, the fact that inflation relative to trend does not affect multipliers in the low unemployment state provides supportive evidence for DNWR, which is at play only in periods of high unemployment. Column (4) also reveals that the difference in multipliers across slack states are a function of inflation relative to trend. Notably, the multiplier in a slack state accompanied with low inflation, estimated to be close to 1, is statistically significantly larger than the multiplier in a low unemployment state, estimated be 0.41. The same is not true for a high unemployment and high inflation multiplier, which is estimated to be much smaller at 0.56. The 2-year cumulative multiplier in a low-inflation recession is statistically different from the 2-year cumulative multiplier in a high inflation expansion. This result is in line with the theoretical prediction that the multiplier in a demand-driven recession is larger than the multiplier in a demand-driven expansion. The gap between the multipliers in the high unemployment state closes at the 4 year horizon where they are around 0.8 across both low and high inflation states. Overall, these results are also consistent with the larger spending multipliers in a demand-driven recession than a supply-driven recession, particularly in the short-run.

5 US state-level empirical evidence

5.1 US state-level data

In order to directly explore how DNWR plays a role in determining the state-dependent fiscal spending multipliers, we exploit U.S. state-level variation in output, inflation and military procurement spending associated with aggregate military buildups. This approach allows us to employ rich state-level data on the degree of binding DNWR, which is possible due to recent advances employing individual-level panel data on wages. While national-level military spending does not exhibit large variations except wartimes, state-level military spending data allows us to exploit the variation across both the time and cross-sectional dimensions. In contrast with the time series analysis in the previous section, which might potentially suffer from confounding factors such as the aggregate monetary policy regimes,[35] US state-level panel regression with time-fixed effects also enables

[35]Earlier literature (see Nakamura and Steinsson (2014); Leeper, Traum, and Walker (2017)) points out that the government spending multipliers are sensitive to aggregate monetary policy, for example, passive or active monetary policy regimes.

us to control for these aggregate factors, such as the stance of monetary policy. A word of caution is also merited since these U.S. state level regressions yield estimates of the local multipliers which are not exactly the same as the aggregate multipliers discussed in previous sections.

The state-level annual data sample starts in 1969 and ends in 2018. State-level nominal GDP is from the US Bureau of Economic Analysis (BEA). In calculating real GDP, we use the US aggregate Consumer Price Index (CPI) to deflate nominal GDP followed by BEA - calculating state-level GDP by applying national price deflator to state-level nominal GDP. State-level employment is from Current Employment Statistics (CES) by the Bureau of Labor Statistics (BLS) and the state-level population is available from the US Census Bureau. We use state-level inflation data constructed by Nakamura and Steinsson (2014) from 1969 to 2008 and later by Zidar (2019) up to 2014. We further extend the state-level inflation from Regional Price Parity (RPP) from Census until 2018.[36]

For state-level military spending, we use data from prime military contracts awarded by the Department of Defense (DOD). Each individual contractor of DOD reports their contract details using DD Form 350, including the service or product supplies, date awarded, principal place of performance, and information about the DOD agency. For each fiscal year between 1966 and 2000, we rely on state-level military prime contract data constructed by Nakamura and Steinsson (2014) For the remaining sample period from 2001 until 2018, we use electronic DD Form 350 data available from www.USAspending.gov.

We measure the extent of binding DNWR as the difference between the share of workers whose year-over-year hourly wage growth rates are (i) zero and (ii) negative for each state and year from 1979 to 2018, constructed by Jo (2021) using the Current Population Survey. Jo (2021) shows that in a recession when employment declines, the share of workers with zero wage changes increases disproportionately more than the share of workers with wage cuts. The paper concludes that a model with DNWR explains the empirical findings the best among alternative wage setting schemes widely discussed in the litera-

[36]Before 1995, Nakamura and Steinsson (2014) use state-level price indices constructed by Del Negro (1998) from 1969. After 1995, both papers by Nakamura and Steinsson (2014) and Zidar (2019) use county and metro level Cost of Living Index (COLI) published by the American Chamber of Commerce Researchers Association (ACCRA), later renamed as Council for Community and Economic Research (C2ER). As regional level COLI is designed to capture differences in price levels across regions within a year, Nakamura and Steinsson (2014) computed the state-level price indices by multiplying population-weighted COLI from the ACCRA for each sate with the US aggregate CPI. We applied for the same procedure to calculate the state-level price indices using the state-level COLI provided by Zidar (2019) and RPP from Census. There are a few missing US state-level inflation observations from Hawaii, Maine, New Hampshire, New Jersey, Rhode Island, and Vermont. We drop those US state-year observations if inflation data is missing.

ture. Grigsby, Hurst, and Yildirmaz (2019) also show similar US-state-level results from 2008 to 2016. Therefore, we use this measure to quantify the degree of binding DNWR for each state and year.

5.2 Econometric approach

The baseline regression equation for the state-level analysis is as follows.

$$\frac{Y_{it} - Y_{it-s}}{Y_{it-s}} = \alpha_i + \gamma_t + \beta \frac{G_{it} - G_{it-s}}{Y_{it-s}} + \text{Controls} + \epsilon_{it}, \tag{10}$$

where Y_{it} denotes per capita real output in state i and G_{it} denotes per capita real military procurement spending in state i in year t, state-fixed effect, α_i, controls for state-specific trends and time-fixed effect, γ_t, controls for aggregate conditions that are common across states such as long-run trend inflation or aggregate monetary policy.

We regress two-year differences in per capita output on the two-year differences in per capita military procurement spending. Both variables are normalized by the two-year lagged per capita output . This normalization helps us control for heteroskedasticity across states, following previous research. We interpret the parameter β of interest as a two-year cumulative spending multiplier. Our military spending data is recorded in the fiscal year, whereas all other data is reported in the calendar year. A biannual regression potentially resolves these time differences as they overlap for most of the time period, following Nakamura and Steinsson (2014) and Dupor and Guerrero (2017).

In order to address endogeneity concerns, namely that the state-level military spending possibly respond to the current macroeconomic status of each state, we instrument our dependent variables with two variables. The first instrumental variable is the sensitivity of each state's changes in military spending with respect to changes in national military spending, which is introduced by Nakamura and Steinsson (2014). The identifying assumption is that the sensitivity is time-invariant and national military spending is exogenous to relative business cycle conditions of each specific state. We use each state's predicted value of military spending, computed as the estimated elasticity $(\widehat{\psi_i})$ times national military spending growth $((G_t - G_{t-s})/Y_{t-s})$, as our instrumental variable.[37]

We also use Bartik type state-specific time-varying instrument variable widely used in the previous literature.[38] We construct it as $B_{it} = s_{it} \frac{G_t - G_{t-2}}{Y_{t-2}}$, where s_{it} is the average level of per capita military procurement spending in that state relative to per capita state

[37]The state-specific sensitivity ψ_i is estimated from the regression equation: $\frac{G_{it} - G_{it-s}}{Y_{it-s}} = \phi_t + \psi_i \frac{G_t - G_{t-s}}{Y_{t-s}} + \epsilon_{it}$.

[38]Nakamura and Steinsson (2014), Demyanyk, Loutskina, and Murphy (2019), and Dupor and Guerrero (2017) among others.

output from the previous two years. Using the predetermined share of military spending, we can avoid the reverse causality concern that state differential military spending can be affected by its state-specific current business cycle conditions.

In order to identify the state-dependent spending multipliers, we add state-level changes in military spending interacted with indicator variables ($\mathbb{I}(\cdot)$), which provide information on US-states-years corresponding to the state of the economy as shown below:

$$\frac{Y_{it} - Y_{it-s}}{Y_{it-s}} = \alpha_i + \gamma_t + \sum_d \beta_d \frac{G_{it} - G_{it-s}}{Y_{it-s}} \mathbb{I}(\text{State } d) + \text{Controls} + \epsilon_{it}. \tag{11}$$

Note that the estimated multipliers with regional data are not directly comparable to the closed economy aggregate multipliers from the time series evidence in Section 4. The estimates from the regional analysis, the so-called open economy relative multipliers, measure the effect of an increase in government spending in one state relative to another state. However, these regional multipliers are useful in testing whether the effectiveness of fiscal policy depends on the US-state-differential conditions of the economy.

We divide the state of economy based on the level of employment, inflation, and DNWR. The indicator variable for low employment, $\mathbb{I}(\text{L}(e_{it}))$ is one when the HP-filtered cyclical component of state-level employment to population ratio (e_{it}) is lower than 25th percentile of its distribution across US-states-and-years and zero otherwise. In addition, $\mathbb{I}(\text{H}(\pi_{it}))$ indicates high inflation US-states-years, which takes the value of one if biannual state-level inflation (π_{it}) is greater than 75th percentile of its distribution and zero otherwise. Lastly, the dummy variable $\mathbb{I}(\text{H}(\text{DNWR}))$ indicates US-states-years when more workers have the binding DNWR constraints. $\mathbb{I}(\text{H}(\text{DNWR}))$ is one when the biannual changes in the state-level differences between the share of workers with zero wage and the share of workers with wage cut is higher than 75% percentile from its distribution across states and years from 1979 to 2018.[39][40] We include one biannual lag of the growth rate of output, military spending, and both instrumental variables in order to meet the lead-lag exogeneity condition suggested by Stock and Watson (2018).[41]

[39] $\mathbb{I}(\text{H}(e_{it}))$, indicating high employment US-states-years, $\mathbb{I}(\text{L}(\pi_{it}))$, representing low inflation US-states-years and $\mathbb{I}(L(\text{DNWR}))$ indicating US-states-years with low DNWR are the complement of their relevant respective state defined above.

[40] Note that the regression specification does not include the level of state-level inflation and the cyclical component of employment themselves but contains dummy variables indicating a high inflation period or a low employment period. This specification is useful to avoid potential measurement errors in state-level measures of inflation, employment, and DNWR. For example, the level of inflation from our data set differs slightly from the one from Hazell, Herreño, Nakamura, and Steinsson (2020) but the indicator of high inflation is almost the same across the two. Our main results are also robust to using the Hazell, Herreño, Nakamura, and Steinsson (2020) state-level inflation data set.

[41] Chen (2019) and Ramey (2020) point out that instrumental variables can be serially correlated in the US-

5.3 US state-level estimation results

Table 7: State-dependent spending multipliers on employment, inflation, and DNWR: Two states

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				Output				
$\frac{G_{it}-G_{it-2}}{Y_{it-2}}$	1.6726***	2.2928**						
	(0.4015)	(0.9190)						
$\frac{G_{it}-G_{it-2}}{Y_{it-2}}\mathbb{I}(\text{H}(e_{it}))$			1.3824***	2.1271				
			(0.4773)	(1.3537)				
$\frac{G_{it}-G_{it-2}}{Y_{it-2}}\mathbb{I}(\text{L}(e_{it}))$			2.3310***	2.6568***				
			(0.4890)	(0.8051)				
$\frac{G_{it}-G_{it-2}}{Y_{it-2}}\mathbb{I}(\text{H}(\pi_{it}))$					2.9197***	4.0850***		
					(0.8281)	(1.3075)		
$\frac{G_{it}-G_{it-2}}{Y_{it-2}}\mathbb{I}(\text{L}(\pi_{it}))$					2.6794***	1.6084		
					(0.9831)	(1.1253)		
$\frac{G_{it}-G_{it-2}}{Y_{it-2}}\mathbb{I}(\text{H}(\text{DNWR}))$							4.0763***	2.4331*
							(1.1559)	(1.4094)
$\frac{G_{it}-G_{it-2}}{Y_{it-2}}\mathbb{I}(\text{L}(\text{DNWR}))$							3.8122***	1.4727
							(1.0552)	(1.2581)
P-value from the test								
$\mathbb{I}(\text{H}(e_{it})) = \mathbb{I}(\text{L}(e_{it}))$			0.11	0.65				
$\mathbb{I}(\text{H}(\pi_{it})) = \mathbb{I}(\text{L}(\pi_{it}))$					0.71	0.02		
$\mathbb{I}(\text{H}(\text{DNWR})) = \mathbb{I}(\text{L}(\text{DNWR}))$							0.74	0.28
Observations	2,450	2,350	2,450	2,350	2,354	2,242	1,450	1,150
Period	1966-2018	1966-2018	1966-2018	1966-2018	1969-2018	1969-2018	1979-2018	1979-2018
Controls		Lagged variables		Lagged variables		Lagged variables		Lagged variables
First-stage F	258.66	6.96	159.00	2.87	19.53	6.71	16.74	30.51
J Statistic	0.17	0.25	4.39	3.56	3.81	4.05	1.29	0.78
Jstat P value	0.68	0.62	0.11	0.17	0.15	0.13	0.52	0.68

Notes: The top panel reports the 2 year cumulative state-level multiplier along with associated standard errors below in parenthesis. The second panel shows p-values testing whether the multipliers are statistically significantly different across states. Two instrumental variables are used for the estimation - sensitivity and Bartik instruments. The lagged variables are added as the control variables in Column (2), (4), (6), and (8). The F-statistic corresponds to the Kleibergen-Paap rk Wald statistic. The J-statistics from overidentification tests are reported. * p<0.10, ** p<0.05, ***p<0.01. Standard errors in parentheses.

Table 7 shows the effect of state-level military procurement spending on output depending upon state-level employment, inflation, and DNWR. To correct for endogeneity bias, we use both instruments - sensitivity and Bartik instruments.[42] The first two columns of Table 7 show the baseline spending multipliers for the entire sample period.

state-level analysis, not satisfying the lead-lag exogeneity requirement that the external instruments should be uncorrelated with past and future shocks. Thus, adding lagged variables in our regression estimation helps to ensure that our instrumental variables have no serial correlation.

[42]The overidentification tests that all instrumental variables are exogenous are not rejected. J statistics from the overidentification test and the corresponding p-values are reported at the bottom of the table.

The two year cumulative multiplier is 1.7, which lies between the estimates using sensitivity IV and Bartik IV from Nakamura and Steinsson (2014).[43] After controlling for lagged variables shown in column (2), the spending multiplier is higher than the one without lagged control variables, while it results in lower first stage F statistics.[44] Column (3) and (4) of Table 7 show the state-dependent spending multipliers depending upon the level of the cyclical component of employment. The spending multipliers for a slack period is higher than the one for non-slack period, although these two coefficients are not statistically different from each other. Column (5) and (6) of Table 7 show the state-dependent spending multipliers depending upon the level of the state-level inflation. Both estimates show the higher spending multiplier for the period of high inflation, but the first stage F statistics are rather low in the case where these differences are statistically significant. The spending multiplier is higher when the US-state-year record high DNWR. Controlling for lagged variables, the estimate on the growth of US state-level military spending interacted with high DNWR indicator is statistically significant while the one interacted with low DNWR indicator is not.

While considering two distinct states do not reveal significantly different effects of spending based on macroeconomic conditions, there is clearer evidence of state-dependence once we allow for interaction between employment, inflation, and DNWR. Table 8 shows three state-dependent spending multipliers, allowing us to identify the source of recession - demand or supply shock driven. Since DNWR cannot be measured early in the sample period, we explore the size of the local spending multiplier based upon employment and inflation for the entire sample period. The spending multiplier is the highest when both employment and inflation are low, periods in which DNWR is most likely to bind (see Column (1)). This is in line with our theory that spending is more effective in a demand-driven recession (i.e. low employment and low inflation) than in a supply-driven recession (i.e. low employment and high inflation).

In order to test directly whether DNWR is a key mechanism in driving the differences of the spending multipliers across states of the economy, we use data on US-state-level degree of DNWR from 1979 to 2018. We find that the spending multiplier is highest for those US-state-year where a slack period coincides with a high degree of DNWR (see Column (2) in Table 8). This finding supports our theory that the government spending is more effective in a recession when DNWR is a binding constraint. The specification in Column (3) introduces four distinct states, allowing us to study differential impact on the spending multipliers relying upon employment, inflation, and DNWR. It shows that the

[43] Note that the sample period of Nakamura and Steinsson (2014) ends in 2008.

[44] This is because autocorrelation coefficients on the control variables change over time.

estimated effects of spending are largest during periods of high DWNR, low employment and low inflation (i.e. a demand-driven recession) and close to being statistically different from the estimates for a high DNWR, low employment, and high inflation (i.e. a supply-driven recession) period.In fact, the multiplier in the high DNWR, low employment and low inflation state is the only one statistically significantly different from zero. The coefficient in a high DNWR, low employment and high inflation state is not precisely estimated due to a small sample size. This is in line with theoretical prediction that DNWR are not likely to bind in a high inflation recession. This result is in agreement with our theory that government spending is more effective in a demand-driven recession with binding DNWR than in a supply-driven recession.

We further consider alternative specifications, where we slice the data differently in Table A.5 in Appendix A.4. For the entire sample period, we find that the spending multiplier is the highest during a demand driven recession with low employment and inflation, without controlling for lagged variable (Column (1)). Controlling for lagged variables, the spending multipliers with high DNWR and low inflation is the only estimate statistically different from zero (Column (2)). We also show (Column (3)) that the spending multiplier in a demand-driven recession accompanied with high DNWR is the highest and this is the only estimate statistically significantly different from zero. The results from this alternative specifications also support our theory that government spending effectively raise output in a demand-driven recession when the DNWR constraint binds.

6 Conclusion

We study the effectiveness of government spending depending on the source of the business cycle and the state of the economy. We first build a New Keynesian model with DNWR, featuring two different sources of the fluctuation: demand and supply shocks. The spending multipliers are different based on the nature of the recession. The simultaneous movement of nominal wage and price matters for the DNWR constraint to have real consequences for labor. Regardless of the sources of fluctuation, nominal wages go down in recessions. Inflation rises in a demand-driven recession and falls in a supply-driven recession. Consequently, in a demand-driven recession, when nominal wage is constrained from downward adjustment, the fall in prices further prevents real wage from adjusting downwards, raising unemployment. As a result, government spending is more effective, since it 1) increases labor without raising wage and 2) raises inflation and the real interest rate to a less degree, leading to less crowing out effect. In a supply-driven recession, prices adjust upward while nominal wage is subject to DNWR, resulting in no real consequences on labor. To this end, the government spending multiplier in a demand-driven recession is much larger than in a supply-driven recession.

We provide empirical evidence that supports these theoretical results using US historical time series data and US state-level panel data. Consistent with theory, we find that the spending multipliers are statistically significantly larger in a low inflation recession than in a high inflation recession. In addition, we show that the spending multiplier is higher in a US-state with a high degree of DNWR in a demand-driven recession.

Our results, overall, provide important implications for the design of economic policy. Notably, we provide evidence that whenever government spending is being considered as a stabilization or a stimulative tool, it is important to recognize the underlying forces driving the economy.

Table 8: State dependent spending multipliers on employment, inflation, and DNWR: Three states

	(1)	(2) Output	(3)
$\frac{G_{it}-G_{it-2}}{Y_{it-2}}\mathbb{I}(\mathrm{H}(e_{it}))$	1.7195	0.8508	0.7633
	(1.1272)	(1.8363)	(1.8220)
$\frac{G_{it}-G_{it-2}}{Y_{it-2}}\mathbb{I}(\mathrm{L}(e_{it}))\mathbb{I}(\mathrm{L}(\pi_{it}))$	3.8621***		
	(1.1890)		
$\frac{G_{it}-G_{it-2}}{Y_{it-2}}\mathbb{I}(\mathrm{L}(e_{it}))\mathbb{I}(\mathrm{H}(\pi_{it}))$	-0.1572		
	(1.1735)		
$\frac{G_{it}-G_{it-2}}{Y_{it-2}}\mathbb{I}(\mathrm{H}(\mathrm{DNWR}))\mathbb{I}(\mathrm{L}(e_{it}))$		3.0136**	
		(1.4104)	
$\frac{G_{it}-G_{it-2}}{Y_{it-2}}\mathbb{I}(\mathrm{L}(\mathrm{DNWR}))\mathbb{I}(\mathrm{L}(e_{it}))$		1.7371*	1.5358
		(1.0147)	(0.9482)
$\frac{G_{it}-G_{it-2}}{Y_{it-2}}\mathbb{I}(\mathrm{H}(\mathrm{DNWR}))\mathbb{I}(\mathrm{L}(e_{it}))\mathbb{I}(\mathrm{H}(\pi_{it}))$			-12.4629
			(8.4444)
$\frac{G_{it}-G_{it-2}}{Y_{it-2}}\mathbb{I}(\mathrm{H}(\mathrm{DNWR}))\mathbb{I}(\mathrm{L}(e_{it}))\mathbb{I}(\mathrm{L}(\pi_{it}))$			3.1180**
			(1.4233)
P-value from the test			
$\mathbb{I}(\mathrm{H}(e_{it})) = \mathbb{I}(\mathrm{L}(e_{it}))\mathbb{I}(\mathrm{L}(\pi_{it}))$	0.16		
$\mathbb{I}(\mathrm{L}(e_{it}))\mathbb{I}(\mathrm{L}(\pi_{it})) = \mathbb{I}(\mathrm{L}(e_{it}))\mathbb{I}(\mathrm{H}(\pi_{it}))$	0.05		
$\mathbb{I}(\mathrm{H}(e_{it})) = \mathbb{I}(\mathrm{H}(\mathrm{DNWR}))\mathbb{I}(\mathrm{L}(e_{it}))$		0.25	
$\mathbb{I}(\mathrm{H}(\mathrm{DNWR}))\mathbb{I}(\mathrm{L}(e_{it})) = \mathbb{I}(\mathrm{L}(\mathrm{DNWR}))\mathbb{I}(\mathrm{L}(e_{it}))$		0.28	
$\mathbb{I}(\mathrm{H}(e_{it})) = \mathbb{I}(\mathrm{H}(\mathrm{DNWR}))\mathbb{I}(\mathrm{L}(e_{it}))\mathbb{I}(\mathrm{L}(\pi_{it}))$			0.22
$\mathbb{I}(\mathrm{H}(\mathrm{DNWR}))\mathbb{I}(\mathrm{L}(e_{it}))\mathbb{I}(\mathrm{H}(\pi_{it})) = \mathbb{I}(\mathrm{H}(\mathrm{DNWR}))\mathbb{I}(\mathrm{L}(e_{it}))\mathbb{I}(\mathrm{L}(\pi_{it}))$			0.06
Observations	2,242	1,150	1,112
Period	1969-2018	1979-2018	1979-2018
Controls	Lagged variables	Lagged variables	Lagged variables
First-stage F	3.52	14.57	15.51
J Statistic	1.89	1.88	3.38
Jstat P value	0.59	0.60	0.50

Notes: The top panel reports the 2 year cumulative state-level multiplier along with associated standard errors below in parenthesis. The second panel shows p-values testing whether the multipliers are statistically significantly different across states. Two instrumental variables are used for the estimation - sensitivity and Bartik instruments. The lagged variables are added as the control variables. The F-statistic corresponds to the Kleibergen-Paap rk Wald statistic. The J-statistics from overidentification tests are reported. * p<0.10, ** p<0.05, ***p<0.01. Standard errors in parentheses.

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Online Appendix to "State dependent government spending multipliers: Downward Nominal Wage Rigidity and Sources of Business Cycle Fluctuations"

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A.1 Appendix: Analytics of state-dependent government spending multipliers

An equilibrium is a set of stochastic processes $\{\lambda_t, c_t, w_t, mc_t, R_t, \pi_t, x_t^1, x_t^2, y_t, n_t, n_t^s, u_t, s_t, p_t^*\}_{t=0}^{\infty}$ satisfying:

$$\lambda_t = (c_t - \chi n_t^{\varphi})^{-\sigma} \tag{A.1}$$

$$\chi \varphi n_t^{s\varphi - 1} = w_t \tag{A.2}$$

$$\lambda_t = R_t \mathbb{E}_t \frac{\beta_{t+1}\lambda_{t+1}}{\pi_{t+1}} \tag{A.3}$$

$$W_t \geq \gamma W_{t-1}; w_t \geq \gamma \frac{w_{t-1}}{\pi_t} \tag{A.4}$$

$$(n_t^s - n_t)(w_t - \gamma \frac{w_{t-1}}{\pi_t}) = 0 \tag{A.5}$$

When DNWR does not bind ($w_t > \gamma \frac{w_{t-1}}{\pi_t}$), full employment is achieved, $n_t^s = n_t$ and $u_t = 0$. As opposed, if DNWR binds, that is, $w_t = \gamma \frac{w_{t-1}}{\pi_t}$, there is an excess supply of labor, $n_t^s > n_t$ and $u_t > 0$.

$$u_t = \frac{n_t^s - n_t}{n_t^s} \tag{A.6}$$

$$p_t^* = \frac{\theta}{\theta - 1} \frac{x_t^1}{x_t^2} \tag{A.7}$$

$$x_t^1 = \lambda_t y_t mc_t + \omega \mathbb{E}_t \beta_{t+1} \pi_{t+1}^{\theta} x_{t+1}^1 \tag{A.8}$$

$$x_t^2 = \lambda_t y_t + \omega \mathbb{E}_t \beta_{t+1} \pi_{t+1}^{\theta-1} x_{t+1}^2 \tag{A.9}$$

$$mc_t = \frac{w_t}{A_t} \tag{A.10}$$

$$\pi_t = \left[\frac{1}{\omega} - \frac{1-\omega}{\omega} p_t^{*1-\theta}\right]^{\frac{1}{\theta-1}} \tag{A.11}$$

$$y_t = A_t n_t / s_t \tag{A.12}$$

$$y_t = c_t + g_t \tag{A.13}$$

$$s_t = (1-\omega) p_t^{*-\theta} + \omega \pi_t^{\theta} s_{t-1} \tag{A.14}$$

$$\frac{R_t}{R} = (\frac{\pi_t}{\pi})^{\alpha_\pi} (\frac{y_t}{y})^{\alpha_y} \tag{A.15}$$

, given exogenous stochastic processes $\{g_t, \beta_t, A_t\}_{t=o}^{\infty}$, which are following AR(1) processes specified as below:

$$\ln \frac{g_t}{g} = \rho^g \ln \frac{g_{t-1}}{g} + \epsilon_t^g \tag{A.16}$$

$$\ln \frac{\beta_t}{\beta} = \rho^\beta \ln \frac{\beta_{t-1}}{\beta} + \epsilon_t^\beta \tag{A.17}$$

$$\ln \frac{A_t}{A} = \rho^A \ln \frac{A_{t-1}}{A} + \epsilon_t^A \tag{A.18}$$

A.1.1 Derivation of IS-PC curves

We derive the IS and the Phillips curve (PC) summarizing equilibrium conditions, (A.1) ~ (A.15). To derive the IS equation, log-linearize both the monetary policy rule (A.15) and the household's intertemporal optimization equation (A.3). Combining the previous two equations yields

$$\widehat{\lambda_t} = \mathbb{E}_t \widehat{\lambda}_{t+1} + \alpha_\pi \widehat{\pi}_t - \mathbb{E}_t \widehat{\pi}_{t+1} + \mathbb{E}_t \widehat{\beta}_{t+1}. \tag{A.19}$$

, where hat variables stand for log-deviations from the steady state and the variable without time subscript represents its steady-state value. Find $\widehat{\lambda}_t$ by log-linearizing the marginal utility of consumption (A.1),

$$\widehat{\lambda_t} = -\frac{\sigma c}{c - \chi n^\varphi} \widehat{c}_t + \frac{\sigma \chi \varphi n^\varphi}{c - \chi n^\varphi} \widehat{n}_t. \tag{A.20}$$

Now let's find the steady-state values of variables. From the production function (A.12), we know that the steady state level of output y=A. Note that the steady-state value of s is zero under the zero inflation steady-state (Galí (2008)). By the market clearing condition (A.13), we find the steady-state consumption is then $c = y - g$. Define the steady-state government spending-to-output ratio as $s_g \equiv \frac{g}{y}$. Then, $c = (1 - s_g)A$. Assume the steady-state labor n equals to labor supply, n^s, which equals to 1. Using Equation (A.2) and (A.10), solve for the model-implied parameter χ assuring $n = 1$ as

$$\chi = \frac{w}{\varphi} = \frac{1}{\varphi} \times A \times mc = \frac{A}{\varphi}\frac{\theta - 1}{\theta}.$$

Substituting the steady-state values to the Equation (A.20) yields

$$\widehat{\lambda_t} = -\frac{\theta(1-s_g)}{\Psi}\widehat{c}_t + \frac{(\theta - 1)}{\Psi}\widehat{n}_t, \tag{A.21}$$

where $\Psi = \frac{\theta\varphi(1-s_g)-(\theta-1)}{\sigma\varphi}$. The log linearization of the market clearing condition (A.13) and the production function (A.12) leads

$$\widehat{c}_t = \frac{1}{1 - s_g}\widehat{y}_t - \frac{s_g}{1 - s_g}\widehat{g}_t \tag{A.22}$$

$$\widehat{y}_t = \widehat{a}_t + (\widehat{n}_t - \widehat{s}_t). \tag{A.23}$$

Galí (2008) shows that $\widehat{s}_t$ equals to zero up to a first-order approximation. Combining (A.19), (A.21), (A.22), and (A.23) yields the IS equation:

$$\widehat{y}_t = \mathbb{E}_t\widehat{y}_{t+1} - (\theta - 1)(\widehat{a}_t - \mathbb{E}_t\widehat{a}_{t+1}) + \theta s_g(\widehat{g}_t - \mathbb{E}_t\widehat{g}_{t+1}) - \Psi(\alpha_\pi\widehat{\pi}_t - \mathbb{E}_t\widehat{\pi}_{t+1}) - \Psi\mathbb{E}_t\widehat{\beta}_{t+1} \tag{A.24}$$

where $\Psi = \frac{\theta\varphi(1-s_g)-\theta+1}{\sigma\varphi}$.

Now let's derive Phillips curve (PC). The PC can be written in two ways, depending upon whether DNWR binds or not. The first-order approximation of Equation (A.7) and (A.11) yields

$$\widehat{\pi}_t = \frac{(1 - \omega)(1 - \omega\beta)}{\omega}\widehat{mc}_t + \beta\mathbb{E}_t\widehat{\pi}_{t+1}, \tag{A.25}$$

where $\widehat{mc}_t$ takes two forms. When DNWR does not bind, full employment is achieved ($\widehat{n}_t = \widehat{n}^s_t$). Log-linearization of the Equation (A.2) under the full employment equilibrium yields $\widehat{w}_t = (\varphi - 1)\widehat{n}_t$. From the Equation (A.10), we know that $\widehat{mc}_t = \widehat{w}_t - \widehat{a}_t$. Combining previous two equations with Equation (A.23) leads

$$\widehat{mc}_t = (\varphi - 1)\widehat{y}_t - \varphi\widehat{a}_t. \tag{A.26}$$

Substituting (A.26) into (A.25) yields the PC curve under the full employment equilibrium:

$$\widehat{\pi}_t = \triangle(\varphi - 1)\widehat{y}_t - \triangle\varphi\widehat{a}_t + \beta\mathbb{E}_t\widehat{\pi}_{t+1}, \tag{A.27}$$

where $\triangle = \frac{(1-\omega)(1-\omega\beta)}{\omega}$. When DNWR binds ($\gamma = 1$), we can re-write $\widehat{w}_t = \widehat{w}_{t-1} - \widehat{\pi}_t$. Then,

$$\widehat{mc}_t = \widehat{w}_{t-1} - \widehat{\pi}_t - \widehat{a}_t. \tag{A.28}$$

Substituting (A.28) into (A.25) yields the modified PC curve under the binding DNWR

$$(1 + \triangle)\widehat{\pi}_t = \triangle[\widehat{w}_{t-1} - \widehat{a}_t] + \beta\mathbb{E}_t\widehat{\pi}_{t+1}. \tag{A.29}$$

A.1.2 Proof of analytical results

Proposition 1. In response to a preference shock, output ($\widehat{y}_t$) and inflation ($\widehat{\pi}_t$) co-move, and in response to a technology shock, output and inflation move in the opposite direction. That is,

$$\frac{\partial\widehat{y}_t}{\partial\widehat{\beta}_{t+1}} < 0; \frac{\partial\widehat{\pi}_t}{\partial\widehat{\beta}_{t+1}} < 0, \text{ and } \frac{\partial\widehat{y}_t}{\partial\widehat{a}_t} > 0; \frac{\partial\widehat{\pi}_t}{\partial\widehat{a}_t} < 0.$$

Proof. Let's consider two independent shock processes. The demand-driven business cycles follow ($\mathbb{E}_t\widehat{\beta}_{t+1} = \widehat{\beta}_{t+1}$, and $\mathbb{E}_t\widehat{\beta}_{t+2} = 0$) where $\mathbb{E}_t\widehat{\beta}_{t+1}$ is β_H in a demand-driven recession and $\mathbb{E}_t\widehat{\beta}_{t+1}$ is β_L in a demand shock-boom. The supply-driven business cycles are to follow ($\widehat{a}_t$=$\widehat{a}_t$, $\mathbb{E}_t\widehat{a}_{t+1}$=$\rho_a\widehat{a}_t$,and $\mathbb{E}_t\widehat{a}_{t+2}$=$\widehat{a}_{t+2}$) where $(\widehat{a}_t, \widehat{a}_{t+2}) = (a_H, a_L)$ in a supply-driven boom and $(\widehat{a}_t, \widehat{a}_{t+2}) = (a_L, a_H)$ in a supply-driven recession. Suppose that the market clearing solution takes the form:

$$\widehat{y}_t = A_y\widehat{g}_t + B_y\mathbb{E}_t\widehat{\beta}_{t+1} + C_y\widehat{a}_t + D_y\mathbb{E}_t\widehat{a}_{t+1} = A_y\widehat{g}_t + B_y\mathbb{E}_t\widehat{\beta}_{t+1} + C_y\widehat{a}_t + \rho_a D_y\widehat{a}_t$$

$$\widehat{\pi}_t = A_\pi\widehat{g}_t + B_\pi\mathbb{E}_t\widehat{\beta}_{t+1} + C_\pi\widehat{a}_t + D_\pi\mathbb{E}_t\widehat{a}_{t+1} = A_\pi\widehat{g}_t + B_\pi\mathbb{E}_t\widehat{\beta}_{t+1} + C_\pi\widehat{a}_t + \rho_a D_\pi\widehat{a}_t.$$

Given the assumptions on shock processes and government spending, the expected output and inflation are

$$\mathbb{E}_t\widehat{y}_{t+1} = A_y\mathbb{E}_t\widehat{g}_{t+1} + B_y\mathbb{E}_t\widehat{\beta}_{t+2} + C_y\mathbb{E}_t\widehat{a}_{t+1} + D_y\mathbb{E}_t\widehat{a}_{t+2} = \rho_a C_y\widehat{a}_t + D_y\widehat{a}_{t+2}$$

$$\mathbb{E}_t\widehat{\pi}_{t+1} = A_\pi\mathbb{E}_t\widehat{g}_{t+1} + B_\pi\mathbb{E}_t\widehat{\beta}_{t+2} + C_\pi\mathbb{E}_t\widehat{a}_{t+1} + D_\pi\mathbb{E}_t\widehat{a}_{t+2} = \rho_a C_\pi\widehat{a}_t + D_\pi\widehat{a}_{t+2}$$

Plug the projected solution into the IS curve (A.24) and Phillips curve (A.27) and solve for coefficients using the method of undetermined coefficients,

$$A_y = \frac{\theta s_g}{1+\Psi\alpha_\pi\triangle(\varphi-1)} > 0$$

$$A_\pi = \frac{\triangle(\varphi-1)\theta s_g}{1+\Psi\alpha_\pi\triangle(\varphi-1)} > 0$$

$$B_y = \frac{\partial\widehat{y}_t}{\partial\widehat{\beta}_{t+1}} = -\frac{\Psi}{[1+\Psi\alpha_\pi\triangle(\varphi-1)]} < 0$$

$$B_\pi = \frac{\partial\widehat{\pi}_t}{\partial\widehat{\beta}_{t+1}} = -\frac{\Psi\triangle(\varphi-1)}{[1+\Psi\alpha_\pi\triangle(\varphi-1)]} < 0$$

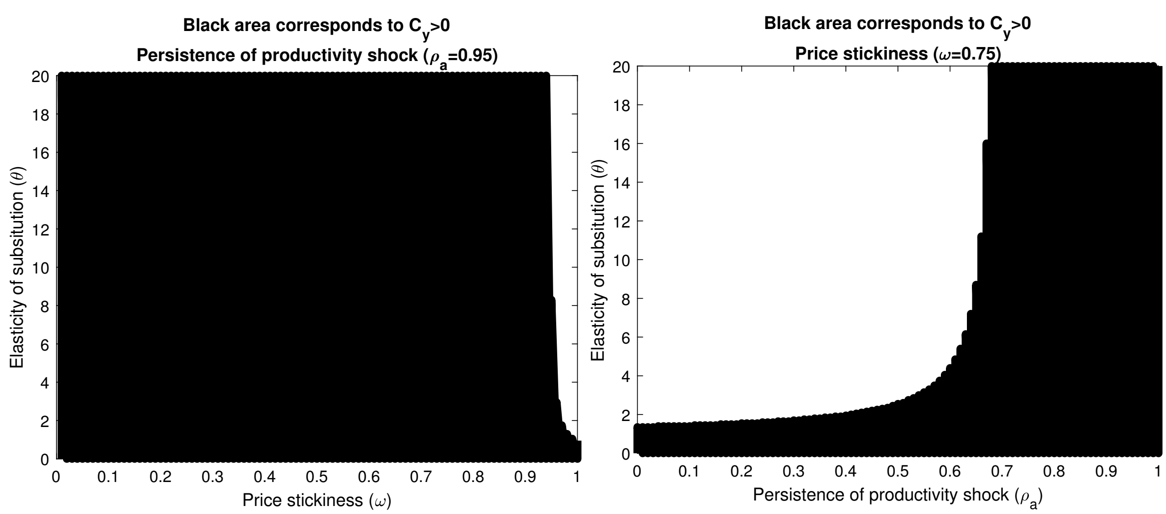
$$D_\pi = 0$$

$$D_y = 0$$

$$C_\pi = \frac{\partial\widehat{\pi}_t}{\partial\widehat{a}_t} = \frac{-\triangle}{(1-\beta\rho_a)}[\frac{(\varphi-1)(\theta-1)(1-\rho_a)(1-\beta\rho_a)+\varphi(1-\rho_a)(1-\beta\rho_a)}{(1-\rho_a)(1-\beta\rho_a)+\Psi(\alpha_\pi-\rho_a)\triangle(\varphi-1)}] < 0$$

$$C_y = \frac{\partial\widehat{y}_t}{\partial\widehat{a}_t} = \frac{-(\theta-1)(1-\rho_a)(1-\beta\rho_a)+\frac{\theta\varphi(1-s_g)-(\theta-1)}{\sigma\varphi}(\alpha_\pi-\rho_a)\frac{(1-\omega)(1-\omega\beta)}{\omega}\varphi}{(1-\rho_a)(1-\beta\rho_a)+\frac{\theta\varphi(1-s_g)-(\theta-1)}{\sigma\varphi}(\alpha_\pi-\rho_a)\frac{(1-\omega)(1-\omega\beta)}{\omega}(\varphi-1)}.$$

Figure A.1: Parameter space corresponding to positive C_y



Notes: The left panel shows the parameter space (θ, ω) that corresponds to positive C_y given the persistence of productivity shock is 0.95. The right panel shows the combination of (θ, ρ_a) that ensures positive C_y.

The sign of all coefficients except C_y is determinant under common parameter values.[1]

[1]The elasticity of substitution parameter θ is greater than 1, the discount factor β is less than 1 and

However, depending on the parameter values, the sign of C_y changes. For example, for a high enough elasticity of substitution (θ) and price-stickiness parameter (ω) or a low enough persistence of productivity shock (ρ_a), C_y can be negative. To determine the sign of C_y, we fix the typical parameter values – the discount factor (β) is 0.99, the Frisch elasticity $(\frac{1}{\varphi-1})$ is 0.5, and Taylor coefficient on inflation (α_π) is 1.5. The steady-state government spending to output ratio s_g is calibrated to 0.2. The left panel of Figure A.1 shows the parameter space of θ and ω that corresponds to positive C_y, under the persistence productivity shock (ρ_a) being 0.95. C_y is positive for plausible parameter space. In New Keynesian literature, it is common to set ω as 0.75. The price rigidity of posted prices varies from 0.45 to 0.73 from microdata literature (see Nakamura and Steinsson (2013)). The right panel of Figure A.1 shows the combination of θ and ρ_a that ensures positive C_y, when the price stickiness parameter, ω, is 0.75. For a high enough persistent productivity, we find that C_y is positive. To summarize, C_y is positive under the plausible parameter space. □

Proposition 2. In a model without DNWR, the government spending multiplier takes the same value M_y in expansion and recession states, i.e. is acyclical.

Proof. From the proof of Proposition 1, the government spending multiplier is

$$M_y \equiv \frac{dy}{dg} = \frac{\partial \widehat{y}_t}{\partial \widehat{g}_t}\frac{\overline{y}}{\overline{g}} = \frac{A_y}{s_g} = \frac{\omega\theta}{\omega + \Psi\alpha_\pi(1-\omega)(1-\omega\beta)(\varphi-1)} \geq 0$$

regardless of the shock processes and the state of the economy. □

Proposition 3. When DNWR binds in period t under the expectation of achieving full employment in period $(t+1)$, the spending multiplier is M_{DNWR} , which is bigger than M_y – the multiplier when DNWR does not bind.

Proof. Guess the solution that satisfies both IS curve (Equation (A.24)) and the modified Phillips curve (Equation (A.29)). Note that the binding DNWR constraint leaves IS curve unchanged while PC changes. Let's first consider the demand-driven business cycle – $(\mathbb{E}_t\widehat{\beta}_{t+1} = \widehat{\beta}_{t+1}$, and $\mathbb{E}_t\widehat{\beta}_{t+2} = 0)$. Then, the projected solution becomes

$$\widehat{y}_t = F_y\widehat{w}_{t-1} + H_y\widehat{g}_t + I_y\mathbb{E}_t\widehat{\beta}_{t+1} \tag{A.30}$$

$$\widehat{\pi}_t = F_\pi\widehat{w}_{t-1} + H_\pi\widehat{g}_t + I_\pi\mathbb{E}_t\widehat{\beta}_{t+1}. \tag{A.31}$$

greater than zero. The government spending share in output, s_g is less than one. The intertemporal elasticity of substitution σ is assumed to be greater than one, while the frequency of price adjustment is ω is less than one. The Taylor coefficient on inflation is assumed to be higher than one.

Under the assumption that DNWR does not bind in period $(t+1)$, the expected output and inflation $\mathbb{E}_t\widehat{y}_{t+1}$ and $\mathbb{E}_t\widehat{\pi}_{t+1}$ become zero. Plug in suggested solutions (A.30) and (A.31) into IS curve (A.24) and the modified Phillips curves (Equation (A.29)) and find the coefficients using the method of undetermined coefficients,

$$F_y\widehat{w}_{t-1} + H_y\widehat{g}_t + I_y\widehat{\beta}_{t+1} = \theta s_g\widehat{g}_t - \Psi\alpha_\pi(F_\pi\widehat{w}_{t-1} + H_\pi\widehat{g}_t + I_\pi\widehat{\beta}_{t+1}) - \Psi\widehat{\beta}_{t+1}$$

$$(1+\triangle)(F_\pi\widehat{w}_{t-1} + H_\pi\widehat{g}_t + I_\pi\widehat{\beta}_{t+1}) = \triangle\widehat{w}_{t-1}$$

The multiplier in the demand-driven business cycle is

$$M^D_{DNWR} = \frac{dy}{dg} = \frac{\partial\widehat{y}_t}{\partial\widehat{g}_t}\frac{y}{g} = H_y\frac{1}{s_g} = \theta$$

, which is bigger than $M_y = \frac{\omega\theta}{\omega+\Psi\alpha_\pi(1-\omega)(1-\omega\beta)(\varphi-1)}$.

Now, let's consider the supply-driven business cycles following ($\widehat{a}_t$=$\widehat{a}_t$, $\mathbb{E}_t\widehat{a}_{t+1}$=$\rho_a\widehat{a}_t$,and $\mathbb{E}_t\widehat{a}_{t+2}$=$\widehat{a}_{t+2}$). Conjecture solution as,

$$\widehat{y}_t = O_y\widehat{w}_{t-1} + S_y\widehat{g}_t + U_y\widehat{a}_t + V_y\rho_a\widehat{a}_t \tag{A.32}$$

$$\widehat{\pi}_t = O_\pi\widehat{w}_{t-1} + S_\pi\widehat{g}_t + U_\pi\widehat{a}_t + V_\pi\rho_a\widehat{a}_t. \tag{A.33}$$

Under the assumption that DNWR does not bind in period $(t+1)$, the expected output and inflation are given by the full employment solution shown in the proof of Proposition 1, as below.

$$\mathbb{E}_t\widehat{y}_{t+1} = C_y\rho_a\widehat{a}_t + D_y\widehat{a}_{t+2} \tag{A.34}$$

$$\mathbb{E}_t\widehat{\pi}_{t+1} = C_\pi\rho_a\widehat{a}_t + D_\pi\widehat{a}_{t+2} \tag{A.35}$$

Combining the suggested solution ((A.32) and (A.33)) with the expected output and inflation ((A.34) and (A.35)) into the IS curve (A.24) and the modified Phillips curves (Equation (A.29)) brings

$$\begin{aligned} O_y\widehat{w}_{t-1} + S_y\widehat{g}_t + U_y\widehat{a}_t + V_y\rho_a\widehat{a}_t = C_y\rho_a\widehat{a}_t + D_y\widehat{a}_{t+2} - (\theta-1)(\widehat{a}_t - \rho_a\widehat{a}_t) \\ + \theta s_g\widehat{g}_t - \Psi\alpha_\pi(O_\pi\widehat{w}_{t-1} + S_\pi\widehat{g}_t + U_\pi\widehat{a}_t + V_\pi\rho_a\widehat{a}_t) + \Psi(C_\pi\rho_a\widehat{a}_t + D_\pi\widehat{a}_{t+2}) \end{aligned}$$

$$(1+\triangle)[O_\pi\widehat{w}_{t-1} + S_\pi\widehat{g}_t + U_\pi\widehat{a}_t + V_\pi\rho_a\widehat{a}_t] = \triangle[\widehat{w}_{t-1} - \widehat{a}_t] + \beta(C_\pi\rho_a\widehat{a}_t + D_\pi\widehat{a}_{t+2})$$

Using the undetermined coefficients method, we find $S_\pi = 0$ and $S_y = \theta s_g$. The output multiplier in the supply-driven business cycle is

$$M^S_{DNWR} = \frac{\partial \widehat{y}}{\partial \widehat{g}}\frac{y}{g} = S_y \frac{1}{s_g} = \theta.$$

Thus, we have shown that the multiplier is θ when DNWR binds (M_{DNWR}), regardless of the source of fluctuation. □

Lemma 1. Assume the economy is at the steady-state in period $t-1$, $\widehat{w}_{t-1} = 0$. In the presence of the DNWR constraint ($\gamma = 1$), a positive discount factor shock or a negative productivity shock triggers the DNWR constraint to bind and induces unemployment in period t.

Proof. Log-linearized DNWR constraint (Equation (A.4)) can be expressed as follows.

$$\widehat{w}_t \geq \gamma(\widehat{w}_{t-1} - \widehat{\pi}_t). \tag{A.36}$$

To show the DNWR constraint binds in period t under the assumption that $\widehat{w}_{t-1} = 0$ and $\gamma = 1$, we have to show

$$\widehat{w}_t + \widehat{\pi}_t < 0. \tag{A.37}$$

Let's conjecture DNWR does not bind and $\widehat{n}_t = \widehat{n}^s_t$. Now check whether the conjecture holds, that is, Equation (A.36) is true. First, we obtain $\widehat{w}_t$ by combining two log-linearized Equation (A.2) and (A.12):

$$\widehat{w}_t = (\varphi - 1)(\widehat{y}_t - \widehat{a}_t).$$

From the proof of Proposition 1, we know that we can write $\widehat{y}_t$ and $\widehat{\pi}_t$ as follows.

$$\widehat{y} = A_y \widehat{g}_t + B_y \mathbb{E}_t \widehat{\beta}_{t+1} + C_y \widehat{a}_t + D_y \mathbb{E}_t \widehat{a}_{t+1} = B_y \mathbb{E}_t \widehat{\beta}_{t+1} + C_y \widehat{a}_t + \rho_a D_y \widehat{a}_t$$

$$\widehat{\pi} = A_\pi \widehat{g}_t + B_\pi \mathbb{E}_t \widehat{\beta}_{t+1} + C_\pi \widehat{a}_t + D_\pi \mathbb{E}_t \widehat{a}_{t+1} = B_\pi \mathbb{E}_t \widehat{\beta}_{t+1} + C_\pi \widehat{a}_t + \rho_a D_\pi \widehat{a}_t$$

Plug in $\widehat{y}_t$ and $\widehat{\pi}_t$ into the left-hand-side of inequality constraint (A.37)

$$\widehat{w}_t + \widehat{\pi}_t = (\varphi - 1)(B_y \mathbb{E}_t \widehat{\beta}_{t+1} + (C_y + \rho_a D_y - 1)\widehat{a}_t) + B_\pi \mathbb{E}_t \widehat{\beta}_{t+1} + (C_\pi + \rho_a D_\pi)\widehat{a}_t$$

In a demand-driven recession, where $\mathbb{E}_t \widehat{\beta}_{t+1} = \beta_H$ and $\widehat{a}_t = 0$,

$$\widehat{w}_t + \widehat{\pi}_t = ((\varphi - 1)B_y + B_\pi)\beta_H.$$

From the proof of Proposition 1, we know coefficients B_y and B_π are negative. Thus, for any positive discount factor shock, we know that

$$\widehat{w}_t + \widehat{\pi}_t < 0,$$

which contradicts the conjecture. Thus, we conclude that DNWR binds in response to a positive discount factor shock.

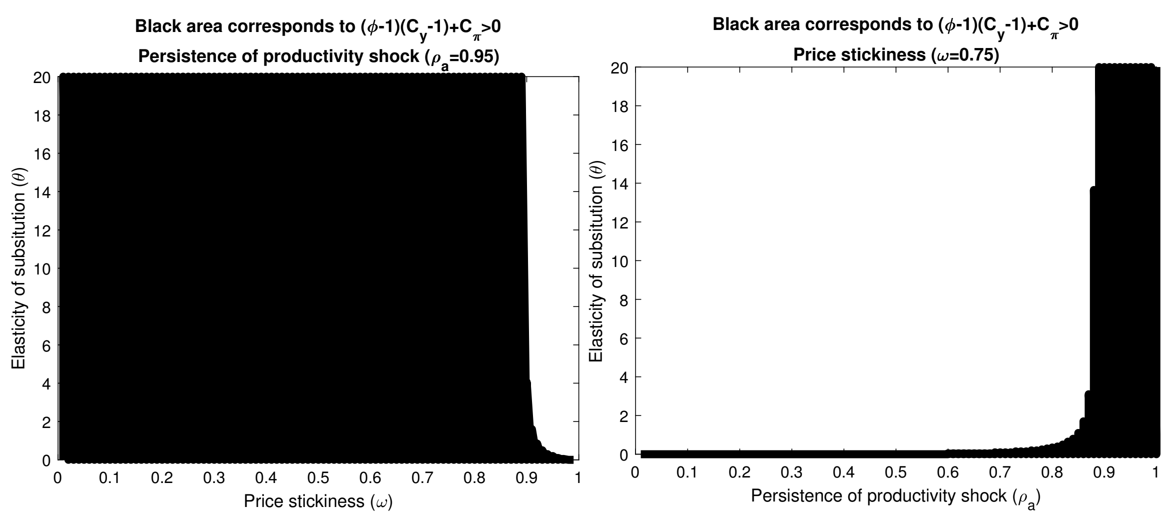
In a supply-driven recession, where $\widehat{a}_t = a_L$ and $\mathbb{E}_t \widehat{\beta}_{t+1} = 0$,

$$\widehat{w}_t + \widehat{\pi}_t = (\varphi - 1)((C_y + \rho_a D_y - 1)a_L) + (C_\pi + \rho_a D_\pi)a_L.$$

As $D_y = D_\pi = 0$, the conjecture that DNWR does not bind is not true if

$$\widehat{w}_t + \widehat{\pi}_t = [(\varphi - 1)(C_y - 1) + C_\pi]a_L < 0.$$

Figure A.2: Parameter space corresponding to positive $(\varphi - 1)(C_y - 1) + C_\pi$



Notes: The left panel shows the parameter space (θ, ω) that gives positive $(\varphi - 1)(C_y - 1) + C_\pi$ given the persistence of productivity shock is 0.95. The right panel shows the combination of (θ, ρ_a) that ensures positive $(\varphi - 1)(C_y - 1) + C_\pi$.

Based on the baseline parameter values[2], the black area in the left panel of Figure A.2 shows the combination of the elasticity of substitution (θ) and the price stickiness (ω) that satisfies

$$[(\varphi - 1)(C_y - 1) + C_\pi] > 0. \tag{A.38}$$

, where the persistence of the productivity shock ρ_a is 0.95. The right panel of FigureA.2

[2]The discount factor (β) is 0.99, the Frisch elasticity $(\frac{1}{\varphi - 1})$ is 0.5, and the Taylor coefficient on inflation (α_π) is 1.5.

shows the combination of θ and ρ_a that satisfies Equation (A.38), when the price stickiness parameter, ω, is 0.75. Under the assumption of highly persistent productivity shock, we conclude that DNWR condition binds. $\square$

Lemma 2. Assume the economy is at steady-state in period $t-1$, $\widehat{w}_{t-1} = 0$. In a demand-driven recession, if government spending is less than $\frac{\Psi}{\theta s_g}\beta_H \equiv c_d(\beta_H)$, the DNWR constraint binds, and unemployment is greater than zero. Otherwise, DNWR is no longer a binding constraint, and unemployment is zero. In a supply-driven recession, if government spending is less than $c_s(a_L)$, the DNWR constraint binds, and unemployment is greater than zero. Otherwise, DNWR is no longer a binding constraint, and unemployment is zero.

Proof. Find the upper bound of nonzero $\widehat{g}_t$ that still violates DNWR condition, that is, $\widehat{w}_t < \gamma(\widehat{w}_{t-1} - \widehat{\pi}_t)$, or $\widehat{w}_t + \widehat{\pi}_t < 0$. With the nonzero government spending $\widehat{g}_t$, we can guess the solution as

$$\widehat{y} = A_y\widehat{g}_t + B_y\mathbb{E}_t\widehat{\beta}_{t+1} + C_y\widehat{a}_t + D_y\mathbb{E}_t\widehat{a}_{t+1} = A_y\widehat{g}_t + B_y\mathbb{E}_t\widehat{\beta}_{t+1} + C_y\widehat{a}_t + \rho_a D_y\widehat{a}_t$$

$$\widehat{\pi} = A_\pi\widehat{g}_t + B_\pi\mathbb{E}_t\widehat{\beta}_{t+1} + C_\pi\widehat{a}_t + D_\pi\mathbb{E}_t\widehat{a}_{t+1} = A_\pi\widehat{g}_t + B_\pi\mathbb{E}_t\widehat{\beta}_{t+1} + C_\pi\widehat{a}_t + \rho_a D_\pi\widehat{a}_t.$$

Then we can rewrite the left-hand-side of the DNWR constraint (A.37)

$$\widehat{w}_t + \widehat{\pi}_t = (\varphi-1)(A_y\widehat{g}_t + B_y\mathbb{E}_t\widehat{\beta}_{t+1} + (C_y + \rho_a D_y - 1)\widehat{a}_t) + A_\pi\widehat{g}_t + B_\pi\mathbb{E}_t\widehat{\beta}_{t+1} + (C_\pi + \rho_a D_\pi)\widehat{a}_t$$

In a demand-driven recession, where $\mathbb{E}_t\widehat{\beta}_{t+1} = \beta_H$ and $\widehat{a}_t = 0$,

$$\widehat{w}_t + \widehat{\pi}_t = ((\varphi-1)A_y + A_\pi)\widehat{g}_t + ((\varphi-1)B_y + B_\pi)\beta_H$$

Using the coefficients that we find from the proof of Proposition 1, we can rewrite the above equation as

$$\widehat{w}_t + \widehat{\pi}_t = (\frac{(\varphi-1)\theta s_g(1+\triangle)}{1+\Psi\alpha_\pi\triangle(\varphi-1)})\widehat{g}_t + (-\frac{\Psi(1+\triangle)(\varphi-1)}{[1+\Psi\alpha_\pi\triangle(\varphi-1)]})\beta_H$$

DNWR binds with non-zero government spending if $\widehat{w}_t + \widehat{\pi}_t < 0$, that is,

$$\frac{(\varphi-1)\theta s_g(1+\triangle)}{1+\Psi\alpha_\pi\triangle(\varphi-1)}\widehat{g}_t < \frac{\Psi(1+\triangle)(\varphi-1)}{1+\Psi\alpha_\pi\triangle(\varphi-1)}\beta_H$$

$$\widehat{g}_t < \frac{\Psi}{\theta s_g}\beta_H \equiv c_d(\beta_H)$$

In a supply-driven recession, where $\widehat{a}_t = a_L$ and $\mathbb{E}_t\widehat{\beta}_{t+1} = 0$, the left-hand-side of the inequality constraint (A.37) is

$$\widehat{w}_t + \widehat{\pi}_t = [(\varphi - 1)A_y + A_\pi]\widehat{g}_t + [(\varphi - 1)(C_y - 1) + C_\pi]a_L.$$

DNWR binds with non-zero government spending if $\widehat{w}_t + \widehat{\pi}_t < 0$, or, equivalently,

$$\widehat{g}_t < \frac{[(\varphi - 1)(C_y - 1) + C_\pi]}{[(\varphi - 1)A_y + A_\pi]}(-a_L) \equiv c_s(a_L) \tag{A.39}$$

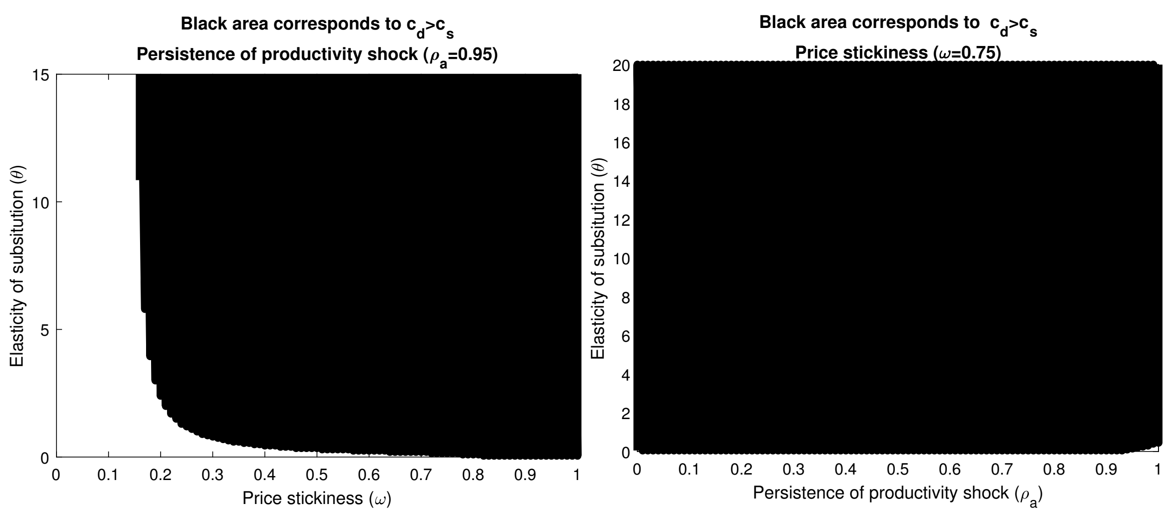
Given the negative productivity shock, the right hand side of Equation (A.39) is positive. Note that we show both A_y and A_π are positive in the proof of Proposition 1 and $[(\varphi - 1)(C_y - 1) + C_\pi]$ is positive from the proof of Lemma 1. □

Lemma 3. Under the assumption that $|\beta_H| = |a_L|$, it can be shown that $0 < c_s(a_L) < c_d(\beta_H)$. In other words, the government spending required to ensure DNWR is no longer binding is smaller in a supply driven recession than a demand driven recession.

Proof. For given $|\beta_H| = |a_L|$, we want to show that

$$\frac{[(\varphi - 1)(C_y - 1) + C_\pi]}{[(\varphi - 1)A_y + A_\pi]} < \frac{\Psi}{\theta s_g} \tag{A.40}$$

Figure A.3: Parameter space corresponding to $c_s(a_L) < c_d(\beta_H)$



Notes: The left panel shows the parameter space (θ, ω) that satisfies $c_s(a_L) < c_d(\beta_H)$ given the persistence of productivity shock is 0.95. The right panel shows the combination of (θ, ρ_a) that ensures $c_s(a_L) < c_d(\beta_H)$.

Based on the baseline parameter values, the black area in the left panel of Figure A.3

shows the combination of the elasticity of substitution (θ) and the price stickiness (ω) that satisfies Equation (A.40), where the persistence of the productivity shock ρ_a is 0.95. The right panel of Figure A.3 shows the combination of θ and ρ_a that satisfies Equation (A.40), when the price stickiness parameter, ω, is 0.75. We find the Equation (A.40) holds for most cases. □

A.2 Appendix: Robustness to alternative degree of nominal rigidity

We also consider an alternative degree of downward nominal wage rigidity and price rigidity. Once we assume a more downwardly flexible wage $(\gamma = 0.96)$, it results in a lower multiplier in a demand-driven recession, as shown in Panel A of Table A.1. In contrast, a more rigid wage rigidity assumption $(\gamma = 0.99)$ leads to higher multipliers in both recessions than the baseline case, reported in Panel B of Table A.1. The main results still hold that the multiplier in a demand-driven recession is higher than the multipliers in a supply-driven recession and expansions. These results confirm that the extent of binding DNWR is one of the key determinants of the size of multipliers.

When considering the dynamics of real wages in a recession, the degree of price rigidity also matters in determining the government spending multiplier. Panel C and D of Table A.1 reports the government spending multipliers with less and more rigid prices than the benchmark case, respectively. Overall, the government spending multipliers are larger in an economy with higher price rigidity, which is seen in a standard New Keynesian model also. With higher price rigidity, an increase in spending raises prices less and labor demand shifts out more due to increased public spending demand, leading to a larger increase in output. This increased price rigidity combined with GHH preferences in Panel C lead to an output multiplier larger than 1, even in an expansion. However, in our specific simulations, price rigidities also matter for the real wage dynamics with DNWR binding. Our results that the spending multipliers are higher in a demand-driven recession are robust for different degrees of price rigidity. In our baseline case, the multiplier in a demand recession is close to 70% larger than in a supply driven recession. With less rigid prices, the multiplier is over 85% larger, since a lower degree of price rigidity further amplifies the difference in real wage response when the DNWR is binding or not. The difference in the multipliers across the two types of recessions shrinks when we have more rigid prices, where the demand recession multiplier is about 45% larger than a supply recession/ expansion multiplier.

Table A.1: Cumulative output and consumption multipliers by the source of fluctuation under alternative degree of wage and price rigidity

		Demand-driven business cycle				Supply-driven business cycle		
		Impact	4 quarters	20 quarters		Impact	4 quarters	20 quarters
				A. Less rigid DNWR ($\gamma = 0.96$)				
Output	Expansion	0.535	0.535	0.535	Expansion	0.535	0.535	0.535
Multiplier	Recession	1.124	0.733	0.649	Recession	0.535	0.535	0.535
Conumption	Expansion	-0.465	-0.465	-0.465	Expansion	-0.465	-0.465	-0.465
Multiplier	Recession	0.124	-0.267	-0.351	Recession	-0.465	-0.465	-0.465
				B. More rigid DNWR ($\gamma = 0.99$)				
Output	Expansion	0.535	0.535	0.535	Expansion	0.535	0.535	0.535
Multiplier	Recession	3.046	2.683	1.849	Recession	1.128	0.734	0.650
Conumption	Expansion	-0.465	-0.465	-0.465	Expansion	-0.465	-0.465	-0.465
Multiplier	Recession	2.046	1.683	0.849	Recession	0.128	-0.266	-0.350
				C. Less rigid prices ($\omega = 0.65$)				
Output	Expansion	0.259	0.259	0.259	Expansion	0.259	0.259	0.259
Multiplier	Recession	1.868	1.067	0.727	Recession	0.259	0.259	0.259
Conumption	Expansion	-0.741	-0.741	-0.741	Expansion	-0.741	-0.741	-0.741
Multiplier	Recession	0.868	0.067	-0.273	Recession	-0.741	-0.741	-0.741
				D. More rigid prices ($\omega = 0.85$)				
Output	Expansion	1.269	1.269	1.269	Expansion	1.269	1.269	1.269
Multiplier	Recession	2.397	1.968	1.674	Recession	1.269	1.269	1.269
Conumption	Expansion	0.269	0.269	0.269	Expansion	0.269	0.269	0.269
Multiplier	Recession	1.397	0.968	0.674	Recession	0.269	0.269	0.269

Notes. This table reports the cumulative output and consumption multipliers in an expansion and a recession depending on the source of fluctuation. The cumulative output and consumption multipliers are calculated as $\Sigma_{i=0}^{i=k-1} \frac{\Delta y_{t+i}}{(1+r_{t+i})} \big/ \Sigma_{i=0}^{i=k-1} \frac{\Delta g_{t+i}}{(1+r_{t+i})}$ and $\Sigma_{i=0}^{i=k-1} \frac{\Delta c_{t+i}}{(1+r_{t+i})} \big/ \Sigma_{i=0}^{i=k-1} \frac{\Delta g_{t+i}}{(1+r_{t+i})}$, respectively, where Δ denotes the level differences of each variable with and without government spending and r_t is the real interest rate.

A.3 Appendix: Time series empirical evidence

Table A.2: State-dependent fiscal multipliers for output: : military news shocks

	(1)	(2)	(3)	(4)	(5)	(6)
	2-year cumulative multiplier			4-year cumulative multiplier		
Σg_t	0.6637***			0.7134***		
	(0.0671)			(0.0436)		
$\Sigma g_t \times \mathbb{I}(L(u_t))$		0.6624***	0.6624***		0.7462***	0.7462***
		(0.1825)	(0.1825)		(0.2638)	(0.2635)
$\Sigma g_t \times \mathbb{I}(H(u_t))$		0.5190***			0.5621***	
		(0.0818)			(0.0757)	
$\Sigma g_t \times \mathbb{I}(H(u_t))\mathbb{I}(L(\pi_t))$			0.7804***			0.5802***
			(0.2631)			(0.1517)
$\Sigma g_t \times \mathbb{I}(H(u_t))\mathbb{I}(H(\pi_t))$			0.2578***			0.5223***
			(0.0738)			(0.1529)
P-value from the test						
$\Sigma g_t \times [\mathbb{I}(L(u_t)) - \mathbb{I}(H(u_t))] = 0$		0.45			0.51	
$\Sigma g_t \times [\mathbb{I}(L(u_t)) - \mathbb{I}(H(u_t))\mathbb{I}(L(\pi_t))] = 0$			0.71			0.57
$\Sigma g_t \times [\mathbb{I}(L(u_t)) - \mathbb{I}(H(u_t))\mathbb{I}(H(\pi_t))] = 0$			0.01			0.45
$\Sigma g_t \times [\mathbb{I}(H(u_t))\mathbb{I}(L(\pi_t)) - \mathbb{I}(H(u_t))\mathbb{I}(H(\pi_t))] = 0$			0.04			0.80
First-stage F statistics						
Linear	19.38			11.22		
$\mathbb{I}(L(u_t))$		15.36	14.93		5.06	4.92
$\mathbb{I}(H(u_t))$					2.75	
$\mathbb{I}(H(u_t))\mathbb{I}(L(\pi_t))$			22.81			9.82
$\mathbb{I}(H(u_t))\mathbb{I}(H(\pi_t))$			19.25			17.83
Observations	493	493	493	485	485	485

Notes: In this robustness check, we consider time-varying thresholds for both the unemployment rate and inflation. The time-varying trend is based on the HP filter with $\lambda = 10^6$, over a split sample, 1889–1929 and 1947–2015 and linearly interpolated for the small gap in trend unemployment between 1929 and 1947, in order to capture the evolution of the natural rate. The high inflation regime is one where inflation is above a HP filtered trend based on $\lambda = 1600$. The top panel panel reports the 2 and 4 year cumulative multiplier along with associated standard errors below. The second panel shows p-values testing whether the multipliers are statistically significantly different across states. The last panel shows the first-stage Fstatistics for military news as an instrument at 2 and 4 year horizons for the given state. * p<0.10, ** p<0.05, ***p<0.01. Standard errors in parentheses.

Table A.3: State-dependent fiscal multipliers for output: military news shocks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	2-year integral output				4-year integral output			
Σg_t	0.6637***				0.7134***			
	(0.0671)				(0.0436)			
$\Sigma g_t \times \mathbb{I}(L(u_{t-1}))$		0.5949***		0.5949***		0.6683***		0.6683***
		(0.0905)		(0.0905)		(0.1236)		(0.1240)
$\Sigma g_t \times \mathbb{I}(H(u_{t-1}))$		0.6029***				0.6820***		
		(0.0888)				(0.0536)		
$\Sigma g_t \times \mathbb{I}(L(\pi_{t-1}))$			0.7285***				0.6774***	
			(0.1090)				(0.0666)	
$\Sigma g_t \times \mathbb{I}(H(\pi_{t-1}))$			0.5980***				0.6951***	
			(0.0581)				(0.0505)	
$\Sigma g_t \times \mathbb{I}(H(u_{t-1}))\mathbb{I}(L(\pi_{t-1}))$				0.9886***				0.7824***
				(0.1878)				(0.0575)
$\Sigma g_t \times \mathbb{I}(H(u_{t-1}))\mathbb{I}(H(\pi_{t-1}))$				-0.1920				0.2044**
				(0.1503)				(0.0998)
P-value from the test								
$\mathbb{I}(L(u_{t-1})) = \mathbb{I}(H(u_{t-1}))$		0.95				0.92		
$\mathbb{I}(L(\pi_{t-1})) = \mathbb{I}(H(\pi_{t-1}))$			0.32				0.82	
$\mathbb{I}(L(u_{t-1})) = \mathbb{I}(H(u_{t-1}))\mathbb{I}(L(\pi_{t-1}))$				0.09				0.47
$\mathbb{I}(L(u_{t-1})) = \mathbb{I}(H(u_{t-1}))\mathbb{I}(H(\pi_{t-1}))$				0.00				0.00
$\mathbb{I}(H(u_{t-1}))\mathbb{I}(L(\pi_{t-1})) = \mathbb{I}(H(u_{t-1}))\mathbb{I}(H(\pi_{t-1}))$				0.00				0.00
First-stage F statistics								
Linear	19.38				11.22			
$\mathbb{I}(L(u_{t-1}))$		8.44		8.07		10.85		10.56
$\mathbb{I}(H(u_{t-1}))$		403.28				130.20		
$\mathbb{I}(L(\pi_{t-1}))$			9.72				5.08	
$\mathbb{I}(H(\pi_{t-1}))$			73.18				45.86	
$\mathbb{I}(H(u_{t-1}))\mathbb{I}(L(\pi_{t-1}))$				56.37				249.55
$\mathbb{I}(H(u_{t-1}))\mathbb{I}(H(\pi_{t-1}))$				45.89				71.63
Observations	493	493	493	493	485	485	485	485

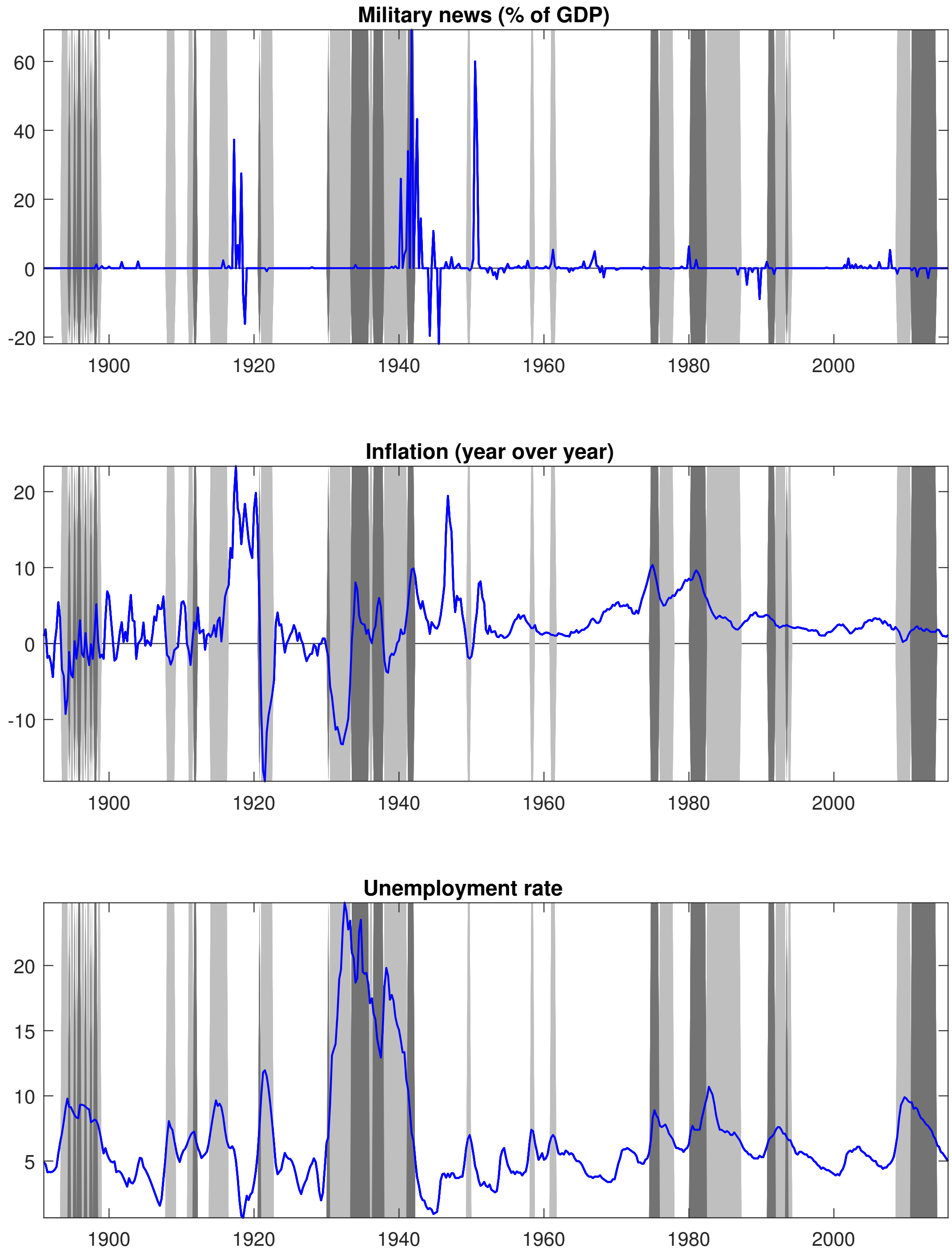
Notes: In this robustness check, we consider time-invariant thresholds for both the unemployment rate and inflation. We consider high or low unemployment periods where the unemployment rate is above or below the threshold of 6.5 %, respectively, as considered by Ramey and Zubairy (2018). We further consider high and low inflation periods, based on quarterly annualized inflation being above or below a threshold of 4%, the top 75th percentile of inflation over the full sample. The top panel panel reports the 2 and 4 year cumulative multiplier along with associated standard errors below. The second panel shows p-values testing whether the multipliers are statistically significantly different across states. The last panel shows the first-stage F statistics for military news as an instrument at 2 and 4 year horizons for the given state. * p<0.10, ** p<0.05, ***p<0.01. Standard errors in parentheses.

Table A.4: State-dependent fiscal multipliers for output: both military news and Blanchard-Perotti (2002) as instruments

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		2-year integral output				4-year integral output		
Σg_t	0.4175***				0.5639***			
	(0.0979)				(0.0837)			
$\Sigma g_t \times \mathbb{I}(L(u_{t-1}))$		0.3343***				0.3873***		
		(0.1095)				(0.1080)		
$\Sigma g_t \times \mathbb{I}(H(u_{t-1}))$		0.6185***				0.6809***		
		(0.0921)				(0.0536)		
$\Sigma g_t \times \mathbb{I}(L(\pi_{t-1}))$			0.3789***				0.4902***	
			(0.1293)				(0.1198)	
$\Sigma g_t \times \mathbb{I}(H(\pi_{t-1}))$			0.5421***				0.6478***	
			(0.0680)				(0.0704)	
$\Sigma g_t \times \mathbb{I}(L(u_{t-1}))\mathbb{I}(L(\pi_{t-1}))$				0.3075*				0.3591*
				(0.1826)				(0.1851)
$\Sigma g_t \times \mathbb{I}(L(u_{t-1}))\mathbb{I}(H(\pi_{t-1}))$				0.4664***				0.5442***
				(0.0416)				(0.0908)
$\Sigma g_t \times \mathbb{I}(H(u_{t-1}))\mathbb{I}(L(\pi_{t-1}))$				0.6805***				0.7900***
				(0.2092)				(0.0621)
$\Sigma g_t \times \mathbb{I}(H(u_{t-1}))\mathbb{I}(H(\pi_{t-1}))$				0.2234*				0.4435***
				(0.1315)				(0.0903)
P-value from the test								
$\mathbb{I}(L(u_{t-1})) = \mathbb{I}(H(u_{t-1}))$		0.10				0.02		
$\mathbb{I}(L(\pi_{t-1})) = \mathbb{I}(H(\pi_{t-1}))$			0.18				0.11	
$\mathbb{I}(L(u_{t-1}))\mathbb{I}(L(\pi_{t-1})) = \mathbb{I}(L(u_{t-1}))\mathbb{I}(H(\pi_{t-1}))$				0.36				0.32
$\mathbb{I}(L(u_{t-1}))\mathbb{I}(L(\pi_{t-1})) = \mathbb{I}(H(u_{t-1}))\mathbb{I}(L(\pi_{t-1}))$				0.72				0.69
$\mathbb{I}(L(u_{t-1}))\mathbb{I}(H(\pi_{t-1})) = \mathbb{I}(H(u_{t-1}))\mathbb{I}(L(\pi_{t-1}))$				0.30				0.04
$\mathbb{I}(H(u_{t-1}))\mathbb{I}(L(\pi_{t-1})) = \mathbb{I}(H(u_{t-1}))\mathbb{I}(H(\pi_{t-1}))$				0.09				0.00
First-stage F statistics								
Linear	64.59				28.40			
$\mathbb{I}(L(u_{t-1}))$		79.26				24.60		
$\mathbb{I}(H(u_{t-1}))$		280.33				72.29		
$\mathbb{I}(L(\pi_{t-1}))$			60.22				26.27	
$\mathbb{I}(H(\pi_{t-1}))$			122.38				14.93	
$\mathbb{I}(L(u_{t-1}))\mathbb{I}(L(\pi_{t-1}))$				56.65				30.76
$\mathbb{I}(L(u_{t-1}))\mathbb{I}(H(\pi_{t-1}))$				36.45				15.87
$\mathbb{I}(H(u_{t-1}))\mathbb{I}(L(\pi_{t-1}))$				55.11				162.35
$\mathbb{I}(H(u_{t-1}))\mathbb{I}(H(\pi_{t-1}))$				69.47				60.69
Observations	493	493	493	493	485	485	485	485

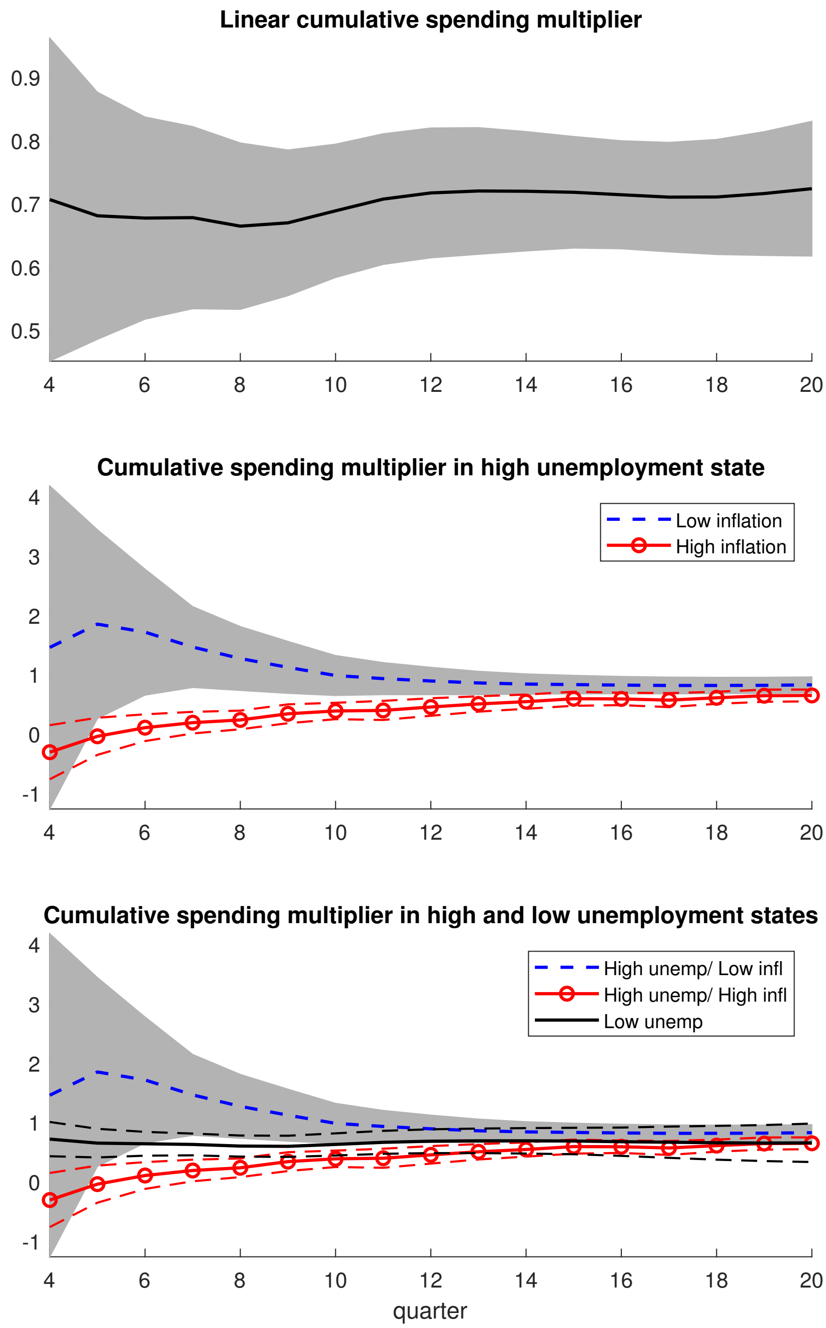
Notes: In this robustness check, we consider time-invariant thresholds for both the unemployment rate and inflation. We consider high or low unemployment periods where the unemployment rate is above or below the threshold of 6.5 %, respectively, as considered by Ramey and Zubairy (2018). We further consider high and low inflation periods, based on quarterly annualized inflation being above or below a threshold of 4%, the top 75th percentile of inflation over the full sample. The top panel panel reports the 2 and 4 year cumulative multiplier along with associated standard errors below. The second panel shows p-values testing whether the multipliers are statistically significantly different across states. The last panel shows the first-stage F statistics for military news and Blanchard and Perotti (2002) shocks jointly as an instrument at 2 and 4 year horizons for the given state. * p<0.10, ** p<0.05, ***p<0.01. Standard errors in parentheses.

Figure A.4: Inflation and unemployment states for U.S. historical data



Notes: Military spending news, year over year GDP deflator inflation rate and the unemployment rate. The shaded areas indicate periods when the unemployment rate is above the threshold of 6.5 percent. The light and dark gray areas correspond with periods where inflation is below and above the hp filtered trend with $\lambda = 1600$, respectively.

Figure A.5: State dependent fiscal multipliers: military news shocks



Notes: These figures show the cumulative multiplier for output in response to a military news shock from 4 quarters after the shock hits the economy. The top panel shows the cumulative multiplier in a linear model. The middle panel shows the state-dependent multiplier in high unemployment/ low inflation (blue dashed) and high unemployment/ high inflation (red circles) states. The bottom panel shows the state dependent multipliers in low unemployment (black solid), high unemployment/ low inflation (blue dashed) and high unemployment/ high inflation (red circles) states. 95 percent confidence intervals are shown in all cases.

A.4 Appendix: US state-level empirical evidence

Table A.5: Alternative specification for state dependent spending multipliers on employment, inflation, and DNWR: Three states

	(1)	(2) Output	(3)
$\frac{G_{it}-G_{it-2}}{Y_{it-2}}\mathbb{I}(\mathrm{H}(\pi_{it}))$	3.7110***	1.3067	1.2319
	(1.1439)	(1.8329)	(1.9313)
$\frac{G_{it}-G_{it-2}}{Y_{it-2}}\mathbb{I}(\mathrm{L}(e_{it}))\mathbb{I}(\mathrm{L}(\pi_{it}))$	3.7154***		
	(1.2097)		
$\frac{G_{it}-G_{it-2}}{Y_{it-2}}\mathbb{I}(\mathrm{H}(e_{it}))\mathbb{I}(\mathrm{L}(\pi_{it}))$	-0.5646		
	(1.4529)		
$\frac{G_{it}-G_{it-2}}{Y_{it-2}}\mathbb{I}(\mathrm{H}(\mathrm{DNWR}))\mathbb{I}(\mathrm{L}(\pi_{it}))$		2.4230*	
		(1.2877)	
$\frac{G_{it}-G_{it-2}}{Y_{it-2}}\mathbb{I}(\mathrm{L}(\mathrm{DNWR}))\mathbb{I}(\mathrm{L}(\pi_{it}))$		1.6184	1.4578
		(1.2405)	(1.4693)
$\frac{G_{it}-G_{it-2}}{Y_{it-2}}\mathbb{I}(\mathrm{H}(\mathrm{DNWR}))\mathbb{I}(\mathrm{L}(e_{it}))\mathbb{I}(\mathrm{L}(\pi_{it}))$			3.0498**
			(1.3843)
$\frac{G_{it}-G_{it-2}}{Y_{it-2}}\mathbb{I}(\mathrm{H}(\mathrm{DNWR}))\mathbb{I}(\mathrm{H}(e_{it}))\mathbb{I}(\mathrm{L}(\pi_{it}))$			1.3834
			(1.8358)
P-value from the test			
$\mathbb{I}(\mathrm{H}(\pi_{it})) = \mathbb{I}(\mathrm{L}(e_{it}))\mathbb{I}(\mathrm{L}(\pi_{it}))$	1.00		
$\mathbb{I}(\mathrm{L}(e_{it}))\mathbb{I}(\mathrm{L}(\pi_{it})) = \mathbb{I}(\mathrm{H}(e_{it}))\mathbb{I}(\mathrm{L}(\pi_{it}))$	0.03		
$\mathbb{I}(\mathrm{H}(\pi_{it})) = \mathbb{I}(\mathrm{H}(\mathrm{DNWR}))\mathbb{I}(\mathrm{L}(\pi_{it}))$		0.56	
$\mathbb{I}(\mathrm{H}(\mathrm{DNWR}))\mathbb{I}(\mathrm{L}(\pi_{it})) = \mathbb{I}(\mathrm{L}(\mathrm{DNWR}))\mathbb{I}(\mathrm{L}(\pi_{it}))$		0.37	
$\mathbb{I}(\mathrm{H}(\pi_{it})) = \mathbb{I}(\mathrm{H}(\mathrm{DNWR}))\mathbb{I}(\mathrm{L}(e_{it}))\mathbb{I}(\mathrm{L}(\pi_{it}))$			0.39
$\mathbb{I}(\mathrm{H}(\mathrm{DNWR}))\mathbb{I}(\mathrm{L}(e_{it}))\mathbb{I}(\mathrm{L}(\pi_{it})) = \mathbb{I}(\mathrm{H}(\mathrm{DNWR}))\mathbb{I}(\mathrm{H}(e_{it}))\mathbb{I}(\mathrm{L}(\pi_{it}))$			0.38
Observations	2,242	1,112	1,112
Period	1969-2018	1979-2018	1979-2018
Controls	Lagged variables	Lagged variables	Lagged variables
First-stage F	5.95	19.50	11.56
J Statistic	2.41	2.86	2.25
Jstat P value	0.49	0.41	0.69

Notes: The top panel reports the 2 year cumulative state-level multiplier along with associated standard errors below in parenthesis. The second panel shows p-values testing whether the multipliers are statistically significantly different across states. Two instrumental variables are used for the estimation - sensitivity and Bartik instruments. The lagged variables are added as the control variables. The F-statistic corresponds to the Kleibergen-Paap rk Wald statistic. The J-statistics from overidentification tests are reported. * p<0.10, ** p<0.05, ***p<0.01. Standard errors in parentheses.