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spending multiplier: It's in the sign**

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Understanding the Size of the Government Spending Multiplier: It's in the Sign*

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Abstract

This paper argues that an important, yet overlooked, determinant of the government spending multiplier is the direction of the fiscal intervention. Regardless of whether we identify government spending shocks from (i) a narrative approach, or (ii) a timing restriction, we find that the contractionary multiplier—the multiplier associated with a negative shock to government spending—is above 1 and largest in times of economic slack. In contrast, the expansionary multiplier—the multiplier associated with a positive shock—is substantially below 1 regardless of the state of the cycle. These results help understand seemingly conflicting results in the literature. A simple theoretical model with incomplete financial markets and downward nominal wage rigidities can rationalize our findings.

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1 Introduction

Understanding the impact of changes in government purchases on output is a key part of fiscal policy analysis, and a large literature has aimed at estimating the size of the government spending multiplier, the change in output caused by a \$1 change in government spending. While earlier studies were conducted within linear frameworks, non-linearities recently received a lot of attention, notably the tantalizing possibility that the multiplier is higher during bad economic times. Unfortunately, despite intense scrutiny the range of estimates for the government spending multiplier remains wide —between 0.5 and 2—, and the effect of economic slack on the multiplier is still highly debated.¹

In this paper, we argue that the direction of the fiscal intervention —expansionary vs contractionary— is an important, yet overlooked, determinant of the spending multiplier.

Using US time series data and standard identification schemes, we study whether changes in government spending have asymmetric effects on output, depending on the direction of the intervention, and whether the degree of asymmetry varies over the business cycle. We allow for asymmetries using an econometric technique —Functional Approximations of Impulse Responses, (FAIR, Barnichon and Matthes, 2018)— that can capture non-linear effects in a flexible yet efficient way. Unlike traditional methods, FAIR allows us to study the asymmetric effects of government spending in conjunction with the two main identification schemes in the literature: the recursive identification (Blanchard and Perotti, 2002, Auerbach and Gorodnichenko, 2012b) and the narrative identification (Ramey, 2011, Ramey and Zubairy, 2018). The literature has often relied on different identification schemes and different empirical methods, a situation that has hampered the emergence of a consensus about the size and properties of the multiplier, as best illustrated by the debate over the putative effect of slack on the multiplier (e.g., Ramey, 2016). By using both identification schemes with the same methodology, we can hope to reach a much more robust set of conclusions.

We find large differences in the effects of expansionary and contractionary spending shocks.

¹For recent work, see e.g., Hall et al. (2009), Mountford and Uhlig (2009), Alesina and Ardagna (2010), Mertens and Ravn (2010), Uhlig (2010), Barro and Redlick (2011), Parker (2011), Ramey (2011, 2012), Auerbach and Gorodnichenko (2012a,2012b), Bachmann and Sims (2012), Owyang et al. (2013), Guajardo et al. (2014), Jordà and Taylor (2016), Ramey and Zubairy (2018), Caggiano et al. (2015), Caldara and Kamps (2017), Alesina et al. (2018), Alesina, Favero, and Giavazzi (2019a, 2019b).

The government spending multiplier is substantially *below* 1 for expansionary shocks to government spending, but the multiplier is *above* 1 for contractionary shocks. We also find that the contractionary spending multiplier is state-dependent —being largest in recessions— but we find little evidence of state-dependence for the expansionary multiplier —being always below 1 and not significantly larger in recessions. Importantly, we reach the same conclusions regardless of the identification strategy.

These results provide a novel explanation for the wide range of state-dependence estimates reported in the government spending literature: while studies based on narratively-identified shocks typically find multipliers below one for both booms and recessions, studies based on recursive identification find that the multiplier is largest and above one during periods of slack.² Our reconciliation hinges on the fact that the relative frequency of expansionary and contractionary shocks differs markedly across the two main identification schemes. Results obtained from a narrative identifying assumption are driven primarily by positive shocks —unexpected *increases* in government spending—, because the narratively-identified shock series contains larger and more numerous positive shocks than negative shocks. As a result, narrative multiplier estimates mostly reflect the effects of positive shocks, which (according to our results) display no detectable state-dependence. In contrast, the spending shocks identified recursively are (by construction) evenly distributed between positive and negative values. As a result, recursive multiplier estimates are larger in recessions, driven by the state-dependent effects of negative shocks.

To interpret our evidence for asymmetric and state-dependent multipliers, we present a stylized model with two key frictions: financial frictions in the form of incomplete markets and borrowing constraints, and labor market frictions, in the form of downward nominal wage rigidities. We illustrate, both with an analytical and a quantitative example, how the presence of these two frictions can give rise to asymmetries and state-dependence, in line with our empirical evidence.

Our model combines the insights from two strands of the literature on business cycles and fiscal multipliers. On the one hand, studies in the New-Keynesian literature have shown that the effects of fiscal policies crucially depend on the presence of credit constrained households, who behave in a “hand-to-mouth” fashion and determine the marginal propensity to consume (MPC)

²Examples include Owyang et al. (2013) and Ramey and Zubairy (2018) who use narratively identified shocks, and Auerbach and Gorodnichenko (2012b, 2012a), Bachmann and Sims (2012), Caggiano et al. (2015), Fazzari et al. (2015) who use recursively identified shocks.

of the aggregate economy.³ Following that literature, we consider a model with heterogeneous agents, uninsurable employment risk, and borrowing constraints. We show that, due to financial frictions, the government spending multiplier can exceed one and fluctuate over time, because the fraction of credit constrained households as well as their consumption share—and in turn the aggregate MPC— can vary in response to economic shocks. On the other hand, and following the original idea of Keynes (1936, Ch. 21), a growing literature is emphasizing the role of downward nominal wage rigidities for explaining key properties of economic fluctuations and the transmission of macroeconomic policies.⁴ As in that literature, we consider an economy where nominal wages adjust more easily downwards than upwards, and wage rigidities are more severe in downturns than during expansions. This gives rise to substantial non-linearities in the effects of aggregate demand shifters, like fiscal policy shocks. We show that, from a theoretical viewpoint, either financial frictions or downward wage rigidities taken in isolation can give rise to asymmetric and state-dependent multipliers. However, from a quantitative viewpoint, our model predicts that the two frictions must be considered simultaneously to account for the magnitude of asymmetry and state-dependence found in the data.⁵

Empirically, an important reason for the lack of time series studies on the asymmetric nature of the government spending multiplier is methodological. The main alternative to our FAIR approach would be to use Local Projections (LP, Jorda, 2005).⁶ However, in a non-linear context LP can only be used if some instruments for the structural shocks have already been independently identified, for instance from a narrative approach. The FAIR methodology can instead be applied in non-linear contexts with both narratively and recursively identified shocks. In addition, the non-parametric nature of LP comes at a large efficiency cost, which implies that in practice LP-based studies can only focus on one non-linearity at a time, e.g. state-dependence

³Recent examples include Galí et al. (2007), Bilbiie et al. (2013), Kaplan and Violante (2014), McKay and Reis (2016) and Auclert et al. (2018). Also, see Bunn et al. (2018) Christelis et al. (2019) for survey-based evidence of asymmetric individual marginal propensity to consume (MPC), which is consistent with asymmetries in the government spending multiplier. For instance, Bunn et al. (2018) find that the MPC out of negative income shocks is above 0.5 but that the MPC out of positive shocks is only about 0.1.

⁴Some examples can be found in Kim and Ruge-Murcia (2009), Benigno and Ricci (2011), Coibion et al. (2012), Abbritti and Fahr (2013), Daly and Hobijn (2014), Schmitt-Grohé and Uribe (2016) and Benigno and Fornaro (2018), among others.

⁵Alternative explanations for state-dependent fiscal multipliers can be found, for example, in Canzoneri et al. (2016) (financial frictions), Michailat and Saez (2015), Ghassibe and Zanetti (2019) (labor market frictions) and Shen and Yang (2018) (downward wage rigidities). Those studies however, abstract from considering asymmetric effects of fiscal expansions and contractions, as we do here.

⁶Structural Vector Autoregressive models (VARs), even regime-switching VARs, cannot be used when the impulse response functions depend on the sign of the shocks. Intuitively, with asymmetric impulse responses, there is no parsimonious auto-regressive representation, because each new shock generates a regime change and the behavior of the economy at any point in time depends on all structural shocks up to that point, leading to a prohibitively large number of state variables. We make this point more formally in the appendix.

as in Ramey and Zubairy (2018).⁷ On the contrary, the parsimonious nature of FAIR allows us to simultaneously study asymmetry and state-dependence.

Our paper also relates to an important literature that estimates the effects of fiscal policy by exploiting additional variation from the cross-section, either from different countries or from different regions within a country.

Regarding cross-country studies, a literature going back at least to Giavazzi and Pagano (1990) and Alesina and Perotti (1997) has studied how changes in the fiscal balance affect economic activity, emphasizing the importance of the timing and the composition of fiscal adjustments. Recent results in that literature indicate that expenditure-based reforms have smaller costs than tax-based reforms, with multipliers typically below one (e.g., Guajardo et al., 2014; Alesina et al., 2018), although Jordà and Taylor (2016) report multipliers above 2 and largest in recessions.⁸ Different from this line of work focused on fiscal contractions, our paper emphasizes the different effects of fiscal contractions and fiscal expansions.

Regarding cross-regional studies, a recent survey by Chodorow-Reich (2019) concludes that the cross-regional multiplier is about 1.8 (e.g., Suárez Serrato and Wingender, 2016; Corbi et al., 2019), substantially larger than found in time-series or cross-country studies, and a number of papers report larger spending multipliers when slack is higher (e.g., Nakamura and Steinsson, 2014), in line with our results.

The paper continues as follows. Section 2 presents the empirical model, our method to approximate impulse responses and the two main structural identifying restrictions used in the literature. Section 3 describes our asymmetric model and presents our results on the asymmetric effects of shocks to government spending. Section 4 describes a model with asymmetry and state-dependence, presents the results and discusses how the asymmetric effects of government spending shocks help reconcile the seemingly contradictory findings in the literature. Section 5 provides some robustness checks, and Section 6 presents a theoretical model to rationalize our findings.

⁷In a similar vein, Hussain and Malik (2016) use LP to study the asymmetric effects of narratively identified tax shocks, while Ziegenbein (2019) explores the state-dependent effect of the same tax shocks.

⁸See also Alesina and Ardagna (2010), Blanchard and Leigh (2013), Alesina et al. (2015), Riera-Crichton et al. (2015), Alesina, Favero, and Giavazzi (2019a, 2019b).

2 Empirical model

Our goal in this paper is to study how the size of the government spending multiplier depends on the sign of the policy intervention and on the state of the business cycle at the time of the policy intervention.

Denoting \mathbf{y}_t a vector of stationary macroeconomic variables, a general model of the economy is given by the structural vector moving-average (VMA) model

$$\mathbf{y}_t = \sum_{k=0}^K \Psi_k(\boldsymbol{\varepsilon}_{t-k}, z_{t-k}) \boldsymbol{\varepsilon}_{t-k} \quad (1)$$

where $\boldsymbol{\varepsilon}_t$ is the vector of i.i.d. structural innovations —shocks— with $\mathbb{E}(\boldsymbol{\varepsilon}_t) = \mathbf{0}$ and $\mathbb{E}(\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_t') = \mathbf{I}$, K is the number of lags, which can be finite or infinite, z_t is a stationary variable that is a function of lagged values of \mathbf{y}_t or a function of variables exogenous to \mathbf{y}_t . Ψ_k is the matrix of lag coefficients —i.e., the matrix of impulse responses at horizon k .

Model (1) is a *non-linear* vector moving average representation of the economy, because the matrix of lag coefficients Ψ_k , i.e., the impulse responses of the economy, can depend on (i) the values of the structural innovations $\boldsymbol{\varepsilon}$ and (ii) the value of the macroeconomic variable z . With Ψ_k a function of $\boldsymbol{\varepsilon}_{t-k}$, the impulse responses to a given structural shock can depend on the sign of that shock. For instance, a positive shock may trigger different impulse responses than a negative shock. With Ψ_k a function of z_{t-k} , the impulse responses to a structural shock depend on the value of z at the time of that shock. For instance, the impulse responses may be different depending on the state of the business cycle (e.g., the level of unemployment) at the time of the shock.

Vector moving-average (VMA) representations like (1) are attractive, because they directly represent the impulse response functions of the economy and thus can easily accommodate non-linear effects of shocks. A well-known limitation of VMAs however is that the parameter space is large, and parameters proliferate quickly when we allow for non-linear effects like asymmetric and state-dependent impulse responses. To give some orders of magnitude, imagine that the horizon of the impulse response is $K = 30$ quarters, and consider a typical quarterly macro US data set made of about 50 years of data, or 200 quarters. In the linear case, i.e., without asymmetry and state-dependence, the number of free parameters is already 30 per impulse response. With asymmetry the number of free parameters doubles to $30 \times 2 = 60$ parameters, and with asymmetry and the simplest form of state-dependence —a binary indicator— the

number of parameters rises to 120 per impulse response. This is much too large to conduct any kind of inference.

While VARs have traditionally been used to shrink the dimension of VMAs, a VAR representation does not exist when shocks have asymmetric effects, because it is not possible to invert the VMA. Instead, we will use a new approach —Functional Approximation of Impulse Responses or FAIR (Barnichon and Matthes, 2018)—, which consists in approximating the impulse responses with a parsimonious function. FAIR is an alternative dimension-reduction tool, which can, unlike VARs, capture asymmetric effects.

In what follows, we explain the intuition and rationale behind our functional approximation, and we describe how we use FAIR with the two main identification schemes in the government spending literature.

2.1 Functional Approximation of Impulse Responses (FAIR)

Since the intuition and benefits of a functional approximation can be understood in a linear context, we first introduce FAIR in a linear context, i.e., where $\Psi_k(\varepsilon_{t-k}, z_{t-k}) = \Psi_k$.

Denote by $\psi(k)$ an element of matrix Ψ_k , so that $\psi(k)$ is the value of an impulse response function ψ at horizon k . The functional approximation of ψ that we consider consists in approximating ψ with a Gaussian function, that is to posit

$$\psi(k) = ae^{-\left(\frac{k-b}{c}\right)^2}, \quad \forall k \in [0, K]. \quad (2)$$

For impulse response functions that are monotonic or hump-shaped, a Gaussian function approximation can offer an “efficient” dimension reduction tool. It reduces the number of parameters substantially — ψ only requires 3 parameters instead of K for an unrestricted impulse response), while still allowing for a large class of impulse responses. With $K = 30$, this amounts to an order-of-magnitude reduction in the number of parameters per impulse response, from 30 to 3.

A second advantage of the Gaussian function approximation is that the three parameters a , b and c have a direct economic interpretation, and in fact capture three separate characteristics of the impulse response. As illustrated in Figure 1, parameter a is the height of the impulse-response, which corresponds to the maximum effect of a unit shock, parameter b is the timing of this maximum effect, and parameter c captures the persistence of the effect of the shock, as

the amount of time τ required for the effect of a shock to be 50% of its maximum value is given by $\tau = c\sqrt{\ln 2}$. These *a-b-c* coefficients are considered the most relevant characteristics of an impulse response function and are generally the most discussed in the literature.

The parsimony and the interpretability of the FAIR approximation will be crucial to allow for asymmetric and state-dependent effects of shocks.

2.2 The structural identifying assumptions

To identify the effects of government spending shocks, the fiscal policy literature has followed two main approaches: (i) identification from a timing assumption, or (ii) identification from narrative sources. In this paper, we will consider both alternatives. As we discuss below, both identification schemes have limitations, but because the limitations are of different natures, comparing results across both schemes may allow the emergence of a much more robust set of results.

For ease of exposition, we will discuss the two main identification schemes in a linear context, postponing the introduction of non-linear effects to the following sections.

Identification from a recursive ordering

The first identification scheme was proposed by Blanchard and Perotti (2002) and consists of a short-run restriction, i.e., a restriction on Ψ_0 , the matrix capturing the contemporaneous impact of a shock. Government spending is assumed to react with a lag to shocks affecting macro variables, so that in a system where \mathbf{y}_t includes government spending, taxes and output, we order government spending first and posit that Ψ_0 has its first row filled with 0 except for the diagonal coefficient. To avoid anticipation effects (Ramey, 2011), we follow Auerbach and Gorodnichenko (2012b) and augment the vector \mathbf{y}_t with a professional forecast of the growth rate of government spending in order to soak up the forecastable components of shocks to public spending.

As shown in details in the appendix, incorporating this identification scheme into a VMA model like (1) is straightforward. In a nutshell the estimation boils down to the estimation of a truncated moving-average model (with a FAIR parametrization). The model can be estimated using maximum likelihood or Bayesian methods, and we recursively construct the likelihood by using the prediction error decomposition and assuming that the structural innovations are Gaussian.

Identification from a narrative approach

The second main identification scheme is based on a narrative approach used in Ramey and Zubairy (2018), which builds on Ramey (2011) and Ramey and Shapiro (1998). Ramey and Zubairy (2018) identify unexpected changes in anticipated future defense expenditures over 1890q1-2014q4 by using news sources from periodicals to measure expectations and expectation surprises. We treat the Ramey-Zubairy news shocks, denoted by ξ_t^g , as external instruments for the government spending shocks ε_t^g . With an external instrument for the spending shocks in hand, it is not necessary to estimate the full VMA model (1). Instead, we can directly estimate the impulse responses of interest.

Denoting the variable of interest (typically output) by y_t and government spending by g_t , we estimate the model

$$\begin{pmatrix} y_t \\ g_t \end{pmatrix} = \sum_{k=0}^K \begin{pmatrix} \varphi_y(k) \\ \varphi_g(k) \end{pmatrix} \xi_{t-k}^g + \begin{pmatrix} u_t^y \\ u_t^g \end{pmatrix} \quad (3)$$

with φ_y and φ_g given by a functional approximation (2) and $\mathbf{u}_t = (u_t^y, u_t^g)'$ the vector of residuals.

Model (3) is similar to a Distributed Lag model but with a few important differences: (i) the right-hand side variable is not the shock itself but a proxy ξ_t^g ; (ii) the functions φ_y and φ_g are approximated with FAIR; and (iii) we allow the vector \mathbf{u}_t to follow a VAR process with

$$\mathbf{u}_t = \mathbf{\Upsilon}(\mathbf{L})\mathbf{u}_{t-1} + \boldsymbol{\eta}_t \quad (4)$$

with $\boldsymbol{\Sigma} = E\boldsymbol{\eta}_t\boldsymbol{\eta}_t'$ and $\mathbf{\Upsilon}(\mathbf{L})$ matrices to be estimated, see the appendix for more details.

Compared to Local Projections with Instrumental Variables (LP-IV, Stock and Watson, 2018)—the method used by Ramey and Zubairy (2018)—, our approach improves estimation efficiency from two separate angles: (i) by parametrizing the impulse responses, and (ii) by effectively modeling the serial- and cross- correlation in the residuals.

On the benefits of using both identification schemes

Both identification schemes have imperfections. The limitation of a recursive identification comes from the limited size of the information set captured by the model. Identifying exogenous innovation to government spending requires the set of control variables to be rich enough to fully control for all the determinants of government spending. However, the information set

may be so large that a time-series model may not be capable of fully capturing the set of relevant determinants of government spending. While controlling for professional forecasts of government spending aims to get at this issue, professional forecasts need not be good proxies for firms’ or households’ forecasts —the relevant expectation measures to control for anticipation effects, see Coibion and Gorodnichenko (2015). As a result a number of researchers prefer to rely on a narrative identification of shocks to government spending.

The limitation of a narrative identification is that its validity relies on subjective judgement. By going through extensive real time sources such as newspaper accounts or reports from governmental institutions, researchers hope to identify true exogenous changes in government spending, i.e., variations in government spending unrelated to developments taking place in the economy. However, this “exogeneity condition” underlying the validity of the identification is not guaranteed to hold, and a number of papers found that some narratively shock series can be predicted with macro variables, thereby questioning the validity of the exogeneity condition.⁹

By using both identification schemes with the same methodology, the hope is to be able to reach a more robust set of conclusions, which do not rely solely on the subjective quality of the narrative identification or on the size of the information set captured by a multivariate time series model.

2.3 Defining the government spending multiplier

We define the government spending multiplier as in Mountford and Uhlig (2009) and Ramey and Zubairy (2018), and we compute the multiplier

$$\mathcal{M}_K = \sum_{k=0}^K \psi_y(k) / \sum_{k=0}^K \psi_g(k) \quad (5)$$

where $\psi_y(\cdot)$ and $\psi_g(\cdot)$ denote respectively the impulse response function of output y and government spending g to a spending shock.

3 The asymmetric government spending multiplier

We now turn to studying the asymmetric effects of government spending shocks. We first describe how to introduce asymmetry in FAIR and then present the estimation results using

⁹See the exchange between Leeper (1997) and Romer and Romer (1997) in the context of identifying monetary shocks narratively, and Jordà and Taylor (2016) in the context of fiscal policy. In contrast, with a model-based (e.g., recursive) identification, the exogeneity condition is guaranteed to hold within the system.

the two identification schemes described in the previous section.

3.1 Introducing asymmetry

Denoting with ψ the impulse response function of some variable to a government spending shock, we allow for asymmetry by letting ψ depend on the sign of the government spending shock ε^g , i.e., the impulse response at horizon k satisfies

$$\psi(k) = \psi^+(k) \mathbb{1}_{\varepsilon_{t-k}^g > 0} + \psi^-(k) \mathbb{1}_{\varepsilon_{t-k}^g < 0}, \quad \forall k \in [0, K] \quad (6)$$

with $\mathbb{1}$ is the indicator function and ψ^+ and ψ^- denote, respectively, the impulse responses to positive and negative government spending shocks.

A one-Gaussian functional approximation of the impulse response function ψ^+ is then

$$\psi^+(k) = a^+ e^{-\left(\frac{k-b^+}{c^+}\right)^2}, \quad \forall k \in [0, K] \quad (7)$$

with a^+ , b^+ , c^+ parameters to be estimated. A similar expression holds for $\psi^-(k)$. The benefit of this approximation is parsimony, as only 6 parameters are needed to capture an asymmetric impulse response.

We then denote with \mathcal{M}^+ the government spending multiplier (5) associated with a positive (expansionary) spending shock and \mathcal{M}^- the multiplier associated with a negative (contractionary) shock.

3.2 Results from a recursive identification scheme

For this part of the analysis, we closely follow the approach of Auerbach and Gorodnichenko (2012), extending their datasets over the sample 1966q3-2014q4. In particular, we consider the vector of variables $\left(\Delta g_{t|t-1}^F, g_t, \tau_t, y_t\right)'$ where g is real government purchases (consumption plus investment at the federal, state, and local levels), τ is real government receipts of direct and indirect taxes net of transfers to businesses and individuals, y is gross domestic product (in chained 2000 dollars), and $\Delta g_{t|t-1}^F$ is the growth rate of government spending at time t forecasted at time $t-1$, which is obtained combining the Greenbook and Survey of Professional Forecasters (SPF) quarterly forecasts. As in Ramey and Zubairy (2018), we ex-ante re-scale all variables by a measure of “potential” output taken from Ramey and Zubairy (2018). The loose priors for the FAIR parameters are detailed in the Appendix.

Figure 2 plots the impulse responses estimated using a symmetric FAIR (“Linear”, dashed black line) and an asymmetric FAIR model (thick solid line). The error bands cover 90 percent of the posterior probability of the asymmetric FAIR model. The upper panel plots the impulse responses to a positive spending shock, while the lower panel plots the impulse responses to a negative shock. When comparing impulse responses to positive and negative shocks, it is important to keep in mind that the impulse responses to negative shocks were multiplied by -1 in order to ease comparison across impulse responses. With this convention, if there is no asymmetry, the impulse responses will be identical in the two panels. Finally, the magnitude of the spending shock is chosen to generate a peak effect on government spending of 1ppt (in absolute value) in order to facilitate the interpretation of the results.

The results show that the impulses responses are strongly asymmetric. Starting with the left panels, we can see that the response of g to a positive spending shock (an expansionary shock, blue line) is similar to the response to a negative spending shock (a contractionary shock, red line), although the response to a negative shock is more persistent.¹⁰ Instead, the response of output is strong following a contractionary g shock but is not significantly different from zero following an expansionary g shock.

The strong asymmetric responses of output imply strong asymmetries in the spending multiplier. As shown the right-most column of Figure 2 and in Table 1, the multiplier to a spending contraction is $\mathcal{M}^- = 1.25$ (cumulating the impulse responses over 20 quarters), while the expansionary multiplier is $\mathcal{M}^+ = 0.27$. The evidence in favor of asymmetry is strong as the posterior probability that $\mathcal{M}^- > \mathcal{M}^+$ is above 0.95 .

3.3 Results from a narrative identification scheme

We next turn to the narrative identification scheme and explore the asymmetry of the multiplier following unexpected changes in anticipated future defense expenditures. We estimate the impulse response functions using the historical data of Ramey and Zubairy (2018) available over 1890-2014.

Similarly to Figure 2, Figure 3 plots the impulse responses of government spending and output to news shocks, and Table 1 reports the corresponding estimates of the multiplier. The

¹⁰In the online appendix, we explore whether the asymmetry in the persistence of positive and negative spending shocks can be behind the asymmetry in the multiplier. We also explore whether asymmetry in the method of financing —taxes vs. deficit— could be behind our results. In both cases, we find no systematic relation with the direction of the shock.

response of output and the size of the multiplier differ markedly between expansionary and contractionary shocks. The multiplier following a positive news shock is lower than 1 with $\mathcal{M}^+ = 0.76$, but the multiplier following a negative shock is above one with $\mathcal{M}^- = 1.36$. These results confirm our previous findings based on a recursive identification scheme, and again the posterior probability that $\mathcal{M}^- > \mathcal{M}^+$ is above 0.95.

4 The asymmetric and state-dependent government spending multiplier

We now allow for the full range of non-linearities and explore whether the size of the multiplier depends on (i) the sign of the shock, and (ii) the state of the business cycle at the time of the shock. We first describe how we introduce state-dependence into a FAIR model and then present the estimation results using the two identification schemes described earlier.

4.1 Introducing asymmetry and state-dependence

To allow for asymmetry and state-dependence in a parsimonious fashion, we approximate the impulse responses ψ^\pm with

$$\psi^\pm(k) = a^\pm(z_{t-k})e^{-\left(\frac{k-b^\pm}{c^\pm}\right)^2}, \quad \forall k > 0. \quad (8)$$

In (8), the amplitude of the impulse response depends on the state of the business cycle (captured by the cyclical indicator z_t) at the time of the shock. Such a specification allows us to test whether a positive fiscal shock has a stronger effect on output in a recession than in an expansion. As cyclical indicator z_t , we use Ramey and Zubairy (2018)'s estimate of cyclical unemployment, shown in Figure 5.

Note that in specification (8) the state of the cycle is allowed to stretch/contract the impulse response, but the shape of the impulse response is fixed (because b and c are independent of z_t). While one could allow for a more general model in which all variables a , b and c depend on the indicator variable, with limited sample size it is necessary to impose some structure on the data, and imposing a constant shape for the impulse response is a natural starting point.¹¹

¹¹In the appendix, we explored using a richer model of non-linearities by also allowing the persistence of the impulse response (c) to depend on the state of the cycle z_t . The main results are similar but subject to larger uncertainty.

4.2 Results from a recursive identification scheme

For the recursive identification scheme, we model state-dependence in a with

$$a^\pm(z_{t-k}) = a_0^\pm(1 + \gamma^\pm z_{t-k}) \quad (9)$$

so we now have two parameters (a_0^\pm and γ^\pm) to capture the loading on the Gaussian basis function. With $\gamma^\pm = 0$, there is no state-dependence and the model reduces to (7) as in the previous section. With $\gamma^\pm > 0$, the magnitude of the impulse response increases linearly with the cyclical indicator z .

Table 2 reports the size of the multiplier in a high unemployment state (detrended unemployment of 2 percent) and in a low unemployment state (detrended unemployment of -1 percent). In addition, Figure 6 illustrates the effect of slack under a slightly different angle, reporting the impulse responses of output at three different levels of (detrended) unemployment.

The stark asymmetry between positive and negative shocks is still present: a contractionary shock has a much larger effect on output than an expansionary shock. Moreover, we do detect some state-dependence, but only for contractionary shocks: the contractionary multiplier is largest in times of high unemployment. Specifically, the contractionary multiplier goes from about 0.9 around business cycle peaks to about 1.5 around business cycle troughs, and the posterior probability that $\mathcal{M}^{-,U \text{ high}} > \mathcal{M}^{-,U \text{ low}}$ is 0.91 (Table 2). In contrast, we not detect state-dependence following expansionary shocks. Overall, \mathcal{M}^+ is small and not significantly different from zero regardless of the level of unemployment.

4.3 Results from a narrative identification scheme

We now perform the same exercise but using the narrative identification scheme of Ramey and Zubairy (2018) over 1890-2014. Since the unemployment rate displayed large fluctuations during the historical sample period, we model state-dependence with a more flexible logit-type function

$$a^\pm(z) = a_0^\pm \left(1 + \gamma^\pm \frac{e^{\beta^\pm z}}{1 + e^{\beta^\pm z}} \right). \quad (10)$$

When β is small, this specification nests the linear model of state-dependence (9), but the extra-flexibility of (10) avoids that unemployment outliers (as observed during the Great Depression) drive our estimates of state-dependence.

The results are displayed in Table 3 and Figure 6. Similar to recursively identified shocks, the contractionary multiplier is about 1 around business cycle peaks but rises to above 1.5 around business cycle troughs, and the posterior probability that $\mathcal{M}^{-,U \text{ high}} > \mathcal{M}^{-,U \text{ low}}$ is high at 0.99. Again, we do not detect state-dependence following expansionary shocks.

4.4 Discussion: A reconciliation of recursive and narrative studies

The consistency of our results across two different identification schemes is alluring, especially in the context of the conflicting estimates reported in the literature. While recursively identified studies report larger multipliers in recessions, narratively identified studies do not find any evidence of state-dependence.

The asymmetric nature of the spending multiplier provides a simple explanation for these conflicting results: the relative frequency of expansionary and contractionary shocks differs markedly across the two main identification schemes. Figure 8 plots the distribution of the Ramey and Zubairy (2018) news shocks along with the distribution of the recursively-identified shocks recovered from our estimated model (1). Unlike with recursively-identified shocks whose distribution is (by construction) roughly evenly distributed between positive and negative shocks, a few very large positive shocks dominate the sample of the Ramey-Zubairy shocks.

Since these studies work under the assumption of symmetric multipliers, their estimated multiplier (and its state-dependence) is a *weighted-average* of the expansionary and contractionary multipliers with the weights depending on the relative frequency of expansionary and contractionary shocks used for estimation. Narratively identified studies based on the Ramey-Zubairy shocks find little evidence for state-dependence, because their results are driven predominantly by positive shocks, which (according to our results) display no detectable state-dependence. In contrast, recursively-identified studies find some evidence for state-dependence, because (roughly) half of the identified shocks are negative shocks, for which we can detect state-dependence.¹²

¹²Consistent with this “shock composition” hypothesis, Ramey and Zubairy (2018) do find significant evidence of state-dependence when they use a recursive identification scheme. Another composition hypothesis is that positive and negative shocks capture different types of spending changes, in particular defense vs. non-defense spending. While the narrative identification is based solely on defense spending, the recursive identification mixes non-defense and defense spending. If these two types of spending have different multipliers (Perotti, 2014) with different state-dependence, a similar composition effect —this time the composition of the positive vs negative recursive shocks— could be behind some of the conflicting results in the literature. To assess this possibility, in the appendix we re-estimate our recursively-identified FAIR model using non-defense government spending alone as our measure of government spending. The results are similar, indicating that the composition of spending —defense vs. non-defense— is not the main driver of our results. More generally, an interesting question for future research is to explore whether the asymmetry depends on the composition of government spending, e.g.,

One caveat to this explanation however is that our two sets of results —recursive vs narrative— are based on very different samples, which makes a comparison across the two identification schemes difficult. In the next robustness section, we address this issue by repeating our estimation exercises over a common sample.

5 Robustness

In this section, we conduct two important robustness checks. First, we repeat our estimation procedures for the two identification schemes using the *same* sample period, namely 1947-2014. Second, we use a different methodology —Local Projections— to assess the size of the bias introduced by our functional approximation of impulse responses.

5.1 Results over 1947-2014

Our results for the two identification schemes are based on different sample periods; a historical period for the narrative identification (1890-2014) and a more recent period (1966-2014) for the recursive identification. While this was done to follow closely the state-of-the-art in the respective literatures, these different sample periods make more difficult a comparison of the results obtained with the different identification schemes.

To make a more direct comparison, we repeat our estimation exercises using the same sample period for both identification schemes. Choosing a common sample period involves some trade-offs, and we use the 1947-2014 sample, which has a number of advantages: (i) it captures a more modern time period without large secular changes in the size and composition of government spending,¹³ (ii) it leaves some large variation in military spending, (iii) there are no outlier movements in government spending (e.g., World War II) that the full-information likelihood-based method (used for the recursive identification) cannot handle with Normal distributed shocks. The downside is that the sample excludes a lot of the Ramey and Zubairy variation, and that the recursive identification is not as clean as we can no longer control for anticipation effects, since g forecast data are not available before 1966.

consumption versus investment (Baxter and King, 1993; Garcia-Milà, 1989; Sims and Wolff, 2018).

¹³As mentioned by Gorodnichenko (2014) in his NBER Summer Institute discussion of Ramey and Zubairy (2018), the post-1947 sample has the advantage of avoiding periods with important regime changes, variation in data quality (Romer, 1986) and secular structural changes (notably a trend in the size and composition of government spending).

Table 3 reports our results for the 1947-2014 sample period. The same conclusion emerges: regardless of the identification scheme, the multiplier is strongly asymmetric and largest in recessions.

5.2 Results using Local Projections

The FAIR method allows us to considerably shrink the dimension of the problem and thereby reduce the variability of our parameter estimates. As with all estimators however, there is a trade-off between efficiency and bias, and one could worry that the functional approximation introduces a large bias in our multiplier estimates. To assess the magnitude of the bias, we turn to Local Projections methods (LP, Jordà, 2005). On the bias-variance spectrum, the LP estimator lies at the opposite end of the FAIR estimator: it imposes no restriction on the impulse response —estimating a separate regression for each impulse response horizon— and thus has no bias (asymptotically), but at the cost of being expensively parametrized and subject to large estimation uncertainty. Similar to VMAs, using LP to estimate asymmetric effects over 30 periods involves estimating 60 parameters per impulse response. With asymmetry and state-dependence, the number of free parameters in LP increases to 120.

Using the Ramey historical data, however, the 1890-2014 sample size is large enough (almost 500 data points) that estimating asymmetric impulse responses with LP is conceivable.¹⁴ The small bias associated with LP will allow us to assess whether using FAIR substantially biases the IRF estimates and drives our results.

As a benchmark, we first consider the linear case without asymmetry. We run linear Local Projections with Instrument Variables, i.e. we estimate $K + 1$ equations

$$y_{t+k} = \alpha_k + \beta_k g_t + \gamma_k' x_t + u_{t+k}, \quad k = 0, 1, \dots, K \quad (11)$$

where y_{t+k} is the variable of interest (government spending or GDP), g_t is government spending at time t that we instrument with the news shock proxy ξ_t^g , and x_t denotes the set of control variables, in this case four lags of y_t and g_t . The impulse response of y_t is then given by $\beta_0, \beta_1, \dots, \beta_K$. We use a horizon of $K = 30$ quarters, and we report Newey et al. (1987) standard errors to allow for autocorrelation in the error terms.

¹⁴That being said, the 500 data points grossly overstate the amount of variation used for identification, because the news shocks are sparse, as they are only about 100 such shocks over the 500 observations. For that reason, allowing for asymmetry *and* state-dependence is just not possible with LP.

To estimate the size of the multiplier along with uncertainty bands, we follow Ramey and Zubairy (2018) and directly estimate the multiplier from the following $K + 1$ linear local projections

$$\sum_{j=0}^k y_{t+j} = \alpha_k + m_k \sum_{j=0}^k g_{t+j} + \gamma'_k x_t + u_{t+k}, \quad k = 0, 1, \dots, K \quad (12)$$

using ξ_t^g as an instrument for $\sum_{j=0}^k g_{t+j}$. Again, x_t contains four lags of y_t and g_t . In (12), the coefficient m_k is directly the estimate of the multiplier \mathcal{M}_k over the first k periods, and the associated standard errors can be readily calculated using the Newey-West estimator.

To allow for asymmetric effects of government spending shocks, we proceed as in the linear case except that we use as instrument either $\left\{ \xi_t^g \mathbb{1}_{\xi_t^g > 0} \right\}$ to get the effect of expansionary shocks or $\left\{ \xi_t^g \mathbb{1}_{\xi_t^g < 0} \right\}$ to get the effect of contractionary shocks.

Figure 4 plots the impulse responses of government spending (g) and output (y), as well as the size of the multiplier (\mathcal{M}) for different horizons, first in the linear case (top row), then in response to an expansionary shock (middle row) and finally in response to a contractionary shock (bottom row). The solid lines report the LP estimates, while the dashed lines report our FAIR estimates.

Overall, the results are very similar across methods: there is no substantial difference in the impulse responses, the size of the multiplier, as well as the magnitude of asymmetric effects between the estimates obtained with LP and FAIR. This indicates that the bias from FAIR is small and does not drive our main findings.¹⁵

6 Asymmetric and state-dependent multipliers: a theoretical explanation

The purpose of this section is to propose a possible explanation for our main empirical findings, namely that the government spending multiplier is larger for contractionary than for expansionary shocks, and larger in periods of economic slack. To that end, we build a standard business cycle model, with two main frictions. First, heterogeneous households are unable to insure against their idiosyncratic income shocks, due to the presence of incomplete financial markets and borrowing constraints. Second, there are frictions in the labor market in the form

¹⁵Keep in mind that LP estimates do not necessarily represent the truth. While LP estimates are asymptotically unbiased (unlike FAIR), in small sample FAIR may be more accurate than LP because of the bias-variance trade-off. What is reassuring is that the FAIR and LP estimates lie close to each other.

of downward nominal wage rigidities, giving rise to cyclical unemployment.

As we will see, either of these frictions can give rise to asymmetric and state-dependent government spending multipliers, but it is the combination of both that can capture quantitatively the size and the cyclical properties of the multiplier. In a nutshell, downward nominal wage rigidities serve to generate the strong convexities in aggregate supply (AS) curve—the (AS) curve being steeper in tight markets—which are necessary to capture the degree of asymmetry and state dependence in the multiplier, while incomplete financial markets serve to amplify the effect of government spending shocks on aggregate demand and allow the model to generate multipliers above one. That being said, alternative demand amplification mechanisms are also possible; a positive spending shock could relax financial constraints through a financial accelerator mechanism (e.g., Bernanke et al., 1999), or imply a redistribution of income and wealth towards agents with a high marginal propensity to consume (e.g., Kaplan and Violante, 2014).

6.1 The environment

Consider an economy with a continuum of heterogeneous households, a continuum of identical firms operating in a perfectly competitive market, and a government in charge of fiscal and monetary policies. There is a homogenous good Y_t , which can be used either for private or government consumption, and labor is the only factor of production.

Technology and labor market frictions. Output of the single good (Y_t) is produced by perfectly competitive firms, according to the production function $Y_t = L_t$. As a result, the firms’ labor demand implies that real wages $W_t/P_t = 1$ in every period. However, frictions in the labor market imply that, at the prevailing wage rate, only a fraction $0 < L_t \leq 1$ of households works, while a fraction $u_t \equiv 1 - L_t$ remains unemployed. In particular, unemployment may arise from two sources. First, the normal churning in the labor market gives rise to “frictional” unemployment: every period an employed household may lose her job with probability $\delta \in (0, 1)$, while an unemployed worker finds a new job opportunity with probability $\chi_t \in (0, 1)$.¹⁶

Second, downward wage rigidities give rise to cyclical “involuntary” unemployment. Following Schmitt-Grohé and Uribe (2016), we assume that wages are downwardly rigid in nominal terms with

$$\frac{W_t}{W_{t-1}} \geq \gamma(u_t), \quad (13)$$

¹⁶Throughout the analysis, as is common in the labor-search literature, cyclical unemployment is associated with changes in the job finding rate χ_t , while the separation rate δ is constant. In other words, unemployment evolves according to $U_t = \delta(1 - U_{t-1}) + (1 - \chi_t)U_{t-1}$.

where $\gamma(u_t)$ is a continuous and twice-differentiable function measuring the severity of the wage rigidity as a function of the unemployment rate u_t , with $\gamma'(\cdot) \leq 0$ and $\gamma''(\cdot) \geq 0$. Specifically, the function $\gamma(\cdot)$ captures (in a reduced-form way) how the severity of downward wage rigidity may vary with the unemployment rate. For instance, as documented in Akerlof et al. (1996), lowering wages may become more and more difficult as the economic gets deeper into a recession or, in other words, the slope of the wage Phillips curve can become flatter in times of slack.¹⁷ In other words, eq. (13) gives rise to an upward-sloping and possibly convex wage Phillips curve. Also, note that specification (13) nests the no-rigidity ($\gamma(u_t) = 0$) and complete downward rigidity ($\gamma(u_t) = 1$) as special cases. The labor supply curve can then be summarized by the following slackness condition

$$(u_t - \bar{u})(W_t - \gamma(u_t)W_{t-1}) = 0, \quad (14)$$

where \bar{u} denotes the “frictional” unemployment rate when the economy operates at full employment, or in the absence of nominal rigidities.

Heterogeneous households and financial frictions. The demand side of the economy is characterized by a continuum of heterogeneous households $i \in [0, 1]$, with identical preferences given by

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_{0,t} \frac{(C_t^i)^{1-\sigma}}{1-\sigma}$$

where C_t^i denotes consumption, $\sigma > 0$ is the coefficient of risk aversion, and $0 < \beta_{0,t} < 1$ is a time-varying discount factor defined recursively by $\beta_{0,t+1} = \beta_{0,t}e^{-(\rho+z_t)}$ for $t = 1, 2, \dots$ with $\beta_{0,0} = 1$, and where $\rho + z_t$ is the implied discount rate. The term z_t is an exogenous aggregate shock and constitutes the only source of aggregate fluctuations, other than fiscal shocks.

Households are assumed to be endowed with one unit of labor, which is supplied inelastically to the labor market. However, in each period, households face idiosyncratic employment shocks $\epsilon_t^i \in \{0, 1\}$, and could either be employed ($\epsilon_t^i = 1$) and receive a labor income W_t , or unemployed ($\epsilon_t^i = 0$) and receive the unemployment subsidy b .

Financial markets are incomplete, and households can only trade in one-period riskless nominal bonds B_t^i subject to a borrowing limit $B_t^i \geq \bar{B} = 0$, which captures in a simple form the presence of frictions in the credit market. As a result, the budget constraint of a generic

¹⁷See Fagan and Messina (2009), Benigno and Ricci (2011) and Daly and Hobijn (2014) for microfounded theories where the presence of wage adjustment costs and idiosyncratic shocks to either individual productivities or to the disutility of labor gives rise to a Phillips curve consistent with (13).

household is given by

$$P_t C_t^i + \frac{B_t^i}{R_t} \leq \epsilon_t^i (W_t - T_t) + (1 - \epsilon_t^i) b + B_{t-1}^i. \quad (15)$$

where P_t denotes the price level, R_t denotes the (gross) nominal interest rate, and T_t denotes (non-distortionary) taxes paid by workers. The assumption that $\bar{B} = 0$ implies that, in equilibrium, all households hold exactly zero wealth, i.e. $B_t^i = 0 \quad \forall i, t$. For this reason, households' choices only depend on the current employment status, and are thus independent on their past employment history.¹⁸

At each point in time the economy thus features only two types of agents: employed (e) and unemployed (u). In addition, we can show that at the equilibrium interest rate —under the plausible assumption that consumption fluctuations due to employment risk are much larger than fluctuations due to aggregate shocks— unemployed agents, who expect high consumption growth, will always be borrowing constrained and effectively behave as hand-to-mouth agents. This implies that their consumption is given by $C^u = b$. Instead, employed households are unconstrained, and their consumption obeys the standard Euler equation

$$(C_t^e)^{-\sigma} = e^{-(\rho+z_t)} R_t \mathbb{E}_t \left\{ \left[(1 - \delta) (C_{t+1}^e)^{-\sigma} + \delta (C^u)^{-\sigma} \right] \Pi_{t+1}^{-1} \right\} \quad (16)$$

where $\Pi_t \equiv P_t/P_{t-1}$ is the gross inflation rate. The right-hand side of the Euler equation shows that the presence of idiosyncratic risk gives rise to a precautionary savings motive: employed individuals consume less, other things equal, because with probability δ they will become unemployed and suffer a fall in consumption (from C_{t+1}^e to C^u).

Fiscal and monetary policies. The government conducts both fiscal and monetary policy. On the fiscal side, the government raises lump-sum taxes on workers to finance unemployment benefits and an exogenous amount of public expenditure G_t , to satisfy in every period the budget constraint¹⁹

$$b u_t + G_t = T_t (1 - u_t). \quad (17)$$

¹⁸In this respect, our model is closely related to the literature developing tractable versions of heterogeneous agent models, as for instance McKay et al. (2017), Ravn and Sterk (2017) and Bilbiie (2018).

¹⁹Even though Ricardian equivalence does not hold in the model, the assumption that taxes are lump-sum and paid only by (financially unconstrained) employed agents could be viewed as an approximation to what would occur under deficit-financed spending. Studying the actual effects of deficit-financed reforms would require incorporating government debt, and the associated wealth distribution in response to fiscal shocks, which is beyond the scope of this paper.

Monetary policy is conducted according to a standard (Taylor-type) interest rate rule

$$R_t = \bar{R}\Pi_t^{\phi_\pi} \quad (18)$$

where \bar{R} is the steady state interest rate, and $\phi_\pi > 1$ denotes the elasticity of the nominal interest rate to inflation.

Equilibrium. For given exogenous paths of demand and government spending shocks, the equilibrium of this economy is a sequence $\{C_t^e, Y_t, T_t, \Pi_t, R_t\}_{t=0}^\infty$, satisfying (14)-(18), together with the goods' market clearing condition. In particular, the equilibrium of the model can be reduced to a system of three relationships, characterizing the behavior of (i) output, (ii) inflation, and (iii) the consumption of employed workers, as a function of the two exogenous disturbances. The first relationship is the goods market clearing condition, given by

$$C_t^e Y_t + C^u (1 - Y_t) = Y_t - G_t, \quad (19)$$

where we have used the fact that, from the production function, the fraction of employed workers $L_t = 1 - u_t = Y_t$.

The second relationship, which is obtained combining (16) and (18) is a (generalized) consumption Euler equation, given by

$$(C_t^e)^{-\sigma} = \bar{R}e^{-(\rho+z_t)}\Pi_t^{\phi_\pi}\mathbb{E}_t \left\{ (C_{t+1}^e)^{-\sigma} \Pi_{t+1}^{-1} \left[(1 - \delta) + \delta \left(\frac{C^u}{C_{t+1}^e} \right)^{-\sigma} \right] \right\}. \quad (20)$$

The third relationship, following from the firms' labor demand $W_t/P_t = 1$ and the slackness condition (14), is the aggregate supply schedule given by

$$(Y_t - \bar{Y}) [\Pi_t - \gamma (1 - Y_t)] = 0, \quad (21)$$

where $\bar{Y} \equiv 1 - \bar{u}$ is the level of output at full-employment.

Given the equilibrium values of $\{C_t^e, Y_t, \Pi_t\}$ satisfying (19) - (21), it is then possible to recover the path of taxes T_t satisfying the government budget constraint (17), and the budget constraint for employed households (15) would also be satisfied, as implied by Walras' law.

6.2 An analytical example

To illustrate the determinants of the fiscal multiplier and the role played by the two frictions—incomplete markets and downward wage rigidities—, it is instructive to consider a special case with no aggregate uncertainty, assuming that from period $t + 1$ onwards there are no shocks, and the economy operates at full-employment (i.e. $G_{t+j} = \bar{G}$ and $z_{t+j} = 0$ for all $j \geq 1$). This economy is represented graphically in Figure 9, which plots the aggregate demand (AD) curve—a combination of (19) and (20)—, and the aggregate supply (AS) curve—equation (21)—, for given future expectations $\{C_{t+1}^e = \bar{C}, \Pi_{t+1} = 1\}$.

As illustrated in Figure 9, an increase in government spending leads to a rightward shift in the (AD) curve, and the size of the multiplier depends on two factors: (i) by how much the (AD) curve shifts in response to the increase in public spending, and (ii) the slope of the (AS) curve, which determines how much of the demand stimulus is absorbed by higher inflation. Thus, two mechanisms can lead to asymmetric and state-dependent multipliers: (i) the (AS) curve is convex—being steeper when aggregate demand is high—, and (ii) government spending leads to different shifts in the (AD) curve depending on the sign of the spending shock or on the underlying economic conditions. As we will see, both mechanisms are operating in our model: downward wage rigidity make the (AS) curve convex, and incomplete markets lead to asymmetric shifts in the (AD) curve.

To understand the determinants of the size of the multiplier, we totally differentiate eq. (19) with respect to G_t to obtain that the (one-period) government spending multiplier $\mathcal{M}_t = \frac{dY_t}{dG_t}$ satisfies

$$\mathcal{M}_t = \frac{1}{1 - m_t} \quad (22)$$

where

$$m_t \equiv \frac{dC_t}{dY_t} = (C_t^e - C^u) + Y_t \frac{dC_t^e}{dY_t} \quad (23)$$

denotes the sensitivity of aggregate consumption to aggregate output.

Notice that eq. (22) is analogous to the expression that would arise in the textbook Keynesian-cross model, where the size of the government spending multiplier is a function of the households' marginal propensity to consume (MPC), and given by $\mathcal{M}_t = 1/(1 - MPC)$. An important difference, however, is that in our setting m_t is not an exogenous constant, but is determined in general equilibrium, taking into account the endogenous responses of prices, wages and the interest rate.

To get an expression for m_t , we note that the consumption of unemployed households is constant and independent of aggregate output, so that we only need an expression for the consumption response of employed households dC_t^e/dY_t . Totally differentiating (20) gives

$$-\sigma (C_t^e)^{-1} \frac{dC_t^e}{dY_t} = \phi_\pi \frac{d\Pi_t}{dY_t} \frac{1}{\Pi_t}, \quad (24)$$

where we have used the fact that the expectation term in eq. (20) is independent of the (temporary) government spending shock. Multiplying both sides of the latter expression by Y_t and rearranging gives

$$Y_t \frac{dC_t^e}{dY_t} = -\phi_\pi \varepsilon_t^{\pi y} \frac{C_t^e}{\sigma} \quad (25)$$

where $\varepsilon_t^{\pi y} \equiv \frac{d\Pi_t}{dY_t} \frac{Y_t}{\Pi_t}$ is the (possibly state-dependent) elasticity of inflation with respect to output. In turn, $\varepsilon_t^{\pi y}$ can be obtained by totally differentiating the aggregate supply curve (21), which gives $\varepsilon_t^{\pi y} \equiv -Y_t \gamma'(\cdot) / \gamma(\cdot) \geq 0$.

Combining (23) and (25) gives

$$m_t = \underbrace{(C_t^e - C^u)}_{\text{“consumption gap”}} - \underbrace{\phi_\pi \varepsilon_t^{\pi y} C_t^e / \sigma}_{\text{“crowding-out”}}. \quad (26)$$

(incomplete markets) (nominal rigidities)

Eq. (26) indicates that m_t (and thus the multiplier \mathcal{M}_t) is determined by the sum of two components which have opposite effects on aggregate consumption: (i) a *positive* effect coming from the consumption gap between employed and unemployed workers, and (ii) a *negative* “crowding-out” effect.

The first component ($C_t^e - C^u$) comes from the existence of financial frictions and captures how a given public spending shock gets amplified and leads to a larger shift in the (AD) curve. An increase in government spending raises income and lowers the unemployment rate. Under incomplete markets, employed households enjoy higher consumption than unemployed ones ($C_t^e - C^u > 0$), so that a lower unemployment rate raises aggregate consumption, and amplifies the effects of a positive government spending shock. This is how the model can generate a positive response of consumption (i.e. $m_t > 0$) and thus a multiplier above one.

The second component comes from the slope of the (AS) curve and captures the negative “crowding-out” effect common to many business cycle models. In fact, that second component

is present for any specification of the demand side of the economy —e.g. even in the standard representative-agent (complete markets) model. Higher government spending raises inflation which, through the central bank’s response, leads to an increase in real interest rates and to a reduction in consumption, as implied by equation (20).²⁰ The magnitude of the crowding-out depends on $\varepsilon_t^{\pi y}$, the elasticity of inflation to output, i.e., on the severity of nominal rigidities. When wages are fully flexible —or equivalently in situations where the downward wage rigidity is not binding— we have that $\varepsilon_t^{\pi y} \rightarrow \infty$ and thus $\mathcal{M}_t \rightarrow 0$: private spending is fully crowded-out by public spending.²¹ Instead, when wages are completely rigid, $\varepsilon_t^{\pi y} = 0$; there is no crowding-out and the multiplier is equal to $\mathcal{M}_t = [1 - (C_t^e - C^u)]^{-1} > 1$. Interestingly, note that the “crowding-out” effect also depends on C_t^e , the total consumption of all employed individuals relative to total output (i.e. $C_t^e(1 - u_t)/Y_t = C_t^e$). The higher is C_t^e , the larger is the share of output that is affected by changes in real interest rates, and the more important is the crowding out effect.

Sources of asymmetry and state-dependence

Expression (26) also makes clear how the model is able to generate asymmetric and state-dependent multipliers. Indeed, we can see that the extent of asymmetry and state dependence depends on the elasticities of $\varepsilon_t^{\pi y}$ and C_t^e , the two variables entering the expression of m_t . Thus, in our model, state-dependent and asymmetric multipliers may arise from two different sources.

The first source of asymmetry and state dependence in \mathcal{M}_t comes from $\varepsilon_t^{\pi y}$. If the inflation-output elasticity is pro-cyclical ($\frac{d\varepsilon_t^{\pi y}}{dY_t} > 0$), as suggested by the empirical evidence that wages become more rigid during recessions (e.g. Akerlof et. al. (1996) and Daly and Hobijn, 2014), the (AS) curve is convex, and the magnitude of the crowding-out effect will vary with the direction of fiscal intervention or with the state of the cycle at the time of the intervention. For instance, as illustrated in Figure 9, higher government spending moves the economy from point A to point B, where the (AS) curve is steeper, and crowding-out is stronger. The opposite happens in response to a reduction in government spending, which exacerbates the severity of downward wage rigidities and lowers the elasticity $\varepsilon_t^{\pi y}$ —the economy moves from point A to point C, where the (AS) curve is flatter and crowding-out weaker. In other words, with downward nominal wage rigidities, expansionary spending shocks have smaller effects on output

²⁰In our model, this channel operates solely through the consumption response of employed households C_t^e , since consumption of the unemployed is constant.

²¹This follows from the fact that in our model there is no wealth effect in the household labor supply. Thus, under flexible prices the only effect of an increase in government spending would be a crowding-out of private consumption.

than contractionary shocks of equal size and $\mathcal{M}_t^+ < \mathcal{M}_t^-$. A similar mechanism generates a counter-cyclical multiplier.

The second source of asymmetry and state dependence in \mathcal{M}_t comes from the response of C_t^e to changes in government spending or in the state of the cycle. As can be seen from (26), two forces are at play because C_t^e enters in two parts of the equation. First, an increase in C_t^e raises the consumption gap between employed and unemployed workers and raises the multiplier, due to the larger consumption gain for each additional employed household. At the same time however, an increase in C_t^e strengthens the “crowding-out” effect, since crowding-out now applies to a larger share of aggregate output. Which of these two effect dominates depends on the sign of $\frac{dm_t}{dC_t^e} = (1 - \phi_\pi \varepsilon_t^{\pi y} / \sigma)$. In economies where wages are relatively rigid and/or the central bank is not too aggressive against inflation, we have that $\phi_\pi \varepsilon_t^{\pi y} / \sigma < 1$, and thus $\frac{dm_t}{dC_t^e} > 0$. This implies that $\mathcal{M}_t^+ < \mathcal{M}_t^-$, as an increase in government spending crowds out private consumption ($dC_t^e/dG_t < 0$). Through a similar reasoning, this also implies that the multiplier is larger in recessions.²²

From this discussion, we can see that either friction —downward wage rigidity or market incompleteness— can give rise to asymmetric and state-dependent government spending multipliers. Indeed, downward wage rigidity works through the first channel by making $\varepsilon_t^{\pi y}$ pro-cyclical, while market incompleteness works through the second channel (provided $\phi_\pi \varepsilon_t^{\pi y} / \sigma < 1$). Quantitatively however, we will now see that both frictions are necessary to capture the size and the cyclical properties of the multiplier.

6.3 A quantitative example

Parameters. To provide a quantitative illustration of the main mechanisms described above, we solve and simulate a calibrated version of the model. Each period is assumed to be a quarter. Economic fluctuations are driven by an exogenous discount factor shocks z_t , following an AR(1) process $z_t = \rho_z z_{t-1} + \varepsilon_t^z$, where $\varepsilon_t^z \sim N(-\sigma_z^2/2, \sigma_z^2)$, and by exogenous government spending shocks $G_t = \bar{G} \exp g_t$, where $g_t = \rho_g g_{t-1} + \varepsilon_t^g$ and $\varepsilon_t^g \sim N(-\sigma_g^2/2, \sigma_g^2)$.

We fix exogenously the discount rate $\rho = 0.01$, the coefficient of risk aversion $\sigma = 2$, and the monetary policy parameter $\phi_\pi = 1.5$, which are standard values in the business cycle literature. Also, the natural unemployment rate \bar{u} (which in our model is the minimum unemployment

²²Notice that, unlike what happens after a positive government spending shock ($\frac{dC_t^e}{dG_t} < 0$), consumption of employed households increases in response to a positive demand shock ($\frac{dC_t^e}{dz_t} > 0$).

rate) is set to 4.5%, which corresponds to the lower bound in the estimates of the natural unemployment rate in the U.S. over the past 100 years (see Barnichon and Matthes, 2017). We also fix the parameters $\rho_g = 0.8$ and $\sigma_g = 0.01$, which correspond to the autocorrelation and standard deviation of government spending in our empirical analysis, and we set $\rho_z = 0.14$ according to the estimates of Fernández-Villaverde et al. (2010). Finally, the monthly separation rate is set to 2%, i.e. $\delta = 1 - (1 - 2\%) = 0.0588$, consistent with the estimate of Elsby et al. (2015).

The remaining parameters ($\bar{G} = 0.1910$, $\sigma_z = 0.062$, $b = 0.3141$, $\gamma_0 = 0.9897$, $\gamma_1 = 33.2824$ and $\gamma_2 = 6.6398$) are set internally, according to the following criteria. First, we choose the value of \bar{G} so that in steady state government expenditure constitutes 20% of GDP. Second, we choose the value of σ_z so that the (stochastic) average of the unemployment rate equals 6 percent, which roughly corresponds to the US average in the period 1948-2018 (recall that without shocks, the unemployment rate would remain at its minimum level). Third, we set the unemployment benefits b so that in steady state the net replacement rate $b/(W - T) = 0.4$, as in Shimer (2005). Finally, we specify a functional form for downward wage rigidities $\gamma(u_t) = \gamma_0 + \frac{1}{\gamma_2}(\gamma_1 u_t)^{\gamma_2}$ and set the parameters $\gamma_0 > 0$ and $\gamma_1 \geq 0$ and $\gamma_2 \geq 0$ to match the following targets, based on the empirical evidence of Daly and Hobijn (2014): (i) at full-employment, nominal wages must grow at a positive rate, i.e. $\gamma(\bar{u}) = 1$; (ii) when unemployment is 1% above its full-employment level, annualized wage deflation cannot exceed 3%; and (iii) when unemployment is 4% above its full-employment level, annualized wage deflation cannot exceed 4%.²³

Solution method. In order to accurately take into account the uncertainty associated with an occasionally binding constraint and capture the potential non-linearities at the heart of our arguments, we solve the model using a global projection method. In particular, we approximate the expectations term in (16) with Chebyshev polynomials on Chebyshev nodes for the two state variables, government spending and discount factor shocks. We then use (19) and (21) to solve for the policy functions of inflation and unemployment. More details are available in the online appendix.

Results. Analogously to our empirical exercise, we compute how the fiscal multiplier varies over the business cycle, both for expansionary and contractionary shocks. To do so, we calculated the impulse responses to a one standard deviation government spending shock (either

²³This parametrization could be viewed as a lower bound on the degree of nominal wage rigidities. During the Great Recession for instance unemployment rose from 5 to 10 percent with almost no decline in nominal wages.

positive or negative), under different realizations of the demand shock z_t , as a proxy for different cyclical conditions of the economy.

The main results are summarized in Table 4 and in Figure 10, which plots the model-implied multiplier over 20 quarters (y-axis), as a function of the (demeaned) unemployment rate (x-axis). For comparison, the figure also reports the posterior median of the FAIR estimates obtained using the recursive identification approach (lines with circles) and the narrative approach (lines with crosses), with the 68% credible sets. The left panel refers to expansionary shocks, and the right panel refers to contractionary shocks. The model predicts a substantial degree of asymmetry in the effects of government spending shocks. For instance, at the average unemployment rate (i.e. detrended unemployment equal to zero), the multiplier for expansionary shocks $\mathcal{M}^+ = 0.47$ is about half the size of the multiplier for contractionary shocks $\mathcal{M}^- = 1.05$. The model also generates countercyclical multipliers, with \mathcal{M}^- ranging from about 1 when the unemployment rate is 1% below average, to 1.25 when unemployment is 2% above average. Thus, the prediction of the model are qualitatively consistent with their empirical counterparts.

From a quantitative viewpoint, the model captures almost entirely the degree of asymmetry observed in the data, and accounts for a substantial portion of the state-dependence —about a third of the estimated increase of \mathcal{M}^- from low-unemployment to high-unemployment states. Also, the model-implied multipliers lie within the 68% bands of the posterior estimates —for at least one identification scheme— at almost all levels of unemployment. The only exception is for expansionary shocks at low levels of unemployment where the model predicts a substantial decline in the multiplier, not observed in the data. This could be because of other theoretical mechanisms not considered in our model, or alternatively because it is simply harder to detect state-dependence for smaller multipliers, due to a higher noise-to-signal ratio.²⁴

To emphasize how the simultaneous presence of incomplete markets and downward nominal rigidities is necessary to rationalize our empirical results, we considered two alternative specifications where we turn off one friction at a time. The second row of Table 4 refers to a version of the model with downward wage rigidity but with complete markets (i.e. setting transfers such that $C_t^e = C_t^u \forall t$), leaving all the model parameters at their baseline values. In that case, the multiplier is always well below 1, both for expansionary and contractionary shocks, and

²⁴The smaller is the multiplier, the smaller is the contribution of government spending shocks to the variance of output, i.e., the higher is the noise-to-signal ratio. Since the expansionary multiplier is small, the degree of state-dependence predicted by our model can be hard to detect, as it is more likely to be swamped by the effects of the other shocks driving output —a problem of high noise-to-signal ratio.

regardless of the level of economic activity. In other words, the presence of downward wage rigidities *per se* is not enough to rationalize the degree of asymmetry found in the data, and the presence of incomplete markets is necessary to rationalize multipliers above unity, in line with our analytical discussion. The third row of Table 4 then refers to a version of the model with incomplete markets but without downward wage rigidities. Specifically, the (AS) curve eq. (21) is replaced with $\Pi_t = \left(\frac{1-u_t}{1-\bar{u}}\right)^{\varepsilon^{\pi y}}$, so that the aggregate supply curve features a constant elasticity.²⁵ In that experiment, the multiplier is larger at about 0.9 but its value is nearly constant regardless of the sign of the shock or the state of the economy. Thus, in our model incomplete markets alone are not sufficient to rationalize the asymmetry and state-dependence found in the data.

7 Conclusion

This paper uses US time series data and standard identification schemes to estimate the asymmetric effects of shocks to government spending. Using either of the two main identification schemes in the literature —recursive or narrative—, we find that the contractionary multiplier is above 1 and larger in recessions, but the expansionary multiplier is always below 1. We show how a model with incomplete financial markets, borrowing constraints, and downward nominal wage rigidities can rationalize this findings.

Looking forward, our findings suggest that taking into account these type of non-linearities could be important for the design of fiscal interventions. While earlier studies emphasized that the ‘when’ and the ‘how’ of fiscal interventions matter (e.g., Alesina et al., 2018), our results imply that fiscal tools may also need to be adjusted depending on the direction of the intended intervention. For instance, in our model with downward wage rigidity and financial frictions, while a reduction in government spending is effective at cooling a booming economy, a temporary employment subsidy —reducing firms’ labor cost in the presence of labor market frictions— is a more effective way to stimulate the economy in times of recession.

²⁵We set $\varepsilon^{\pi y} = 1.44$, which corresponds to the value of the elasticity when unemployment equals its average of 6 percent in our baseline case.

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FAIR, 1 Gaussian

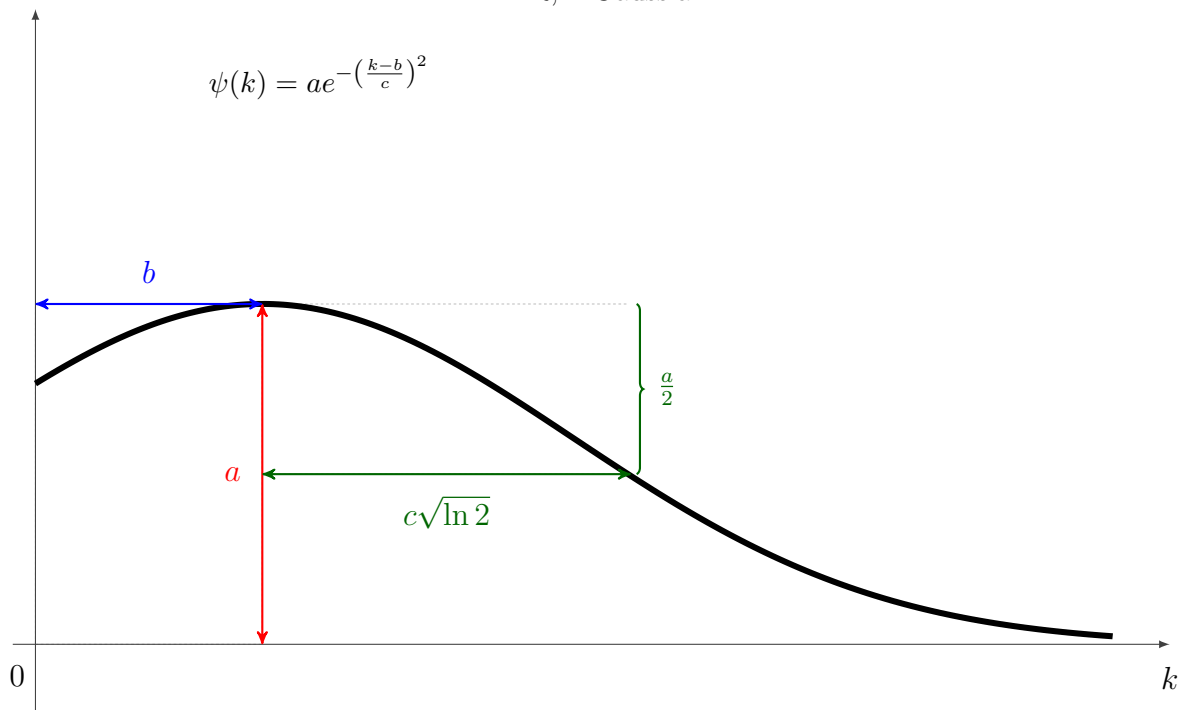


Figure 1: **Functional Approximation of Impulse Responses (FAIR)** with one Gaussian basis function.

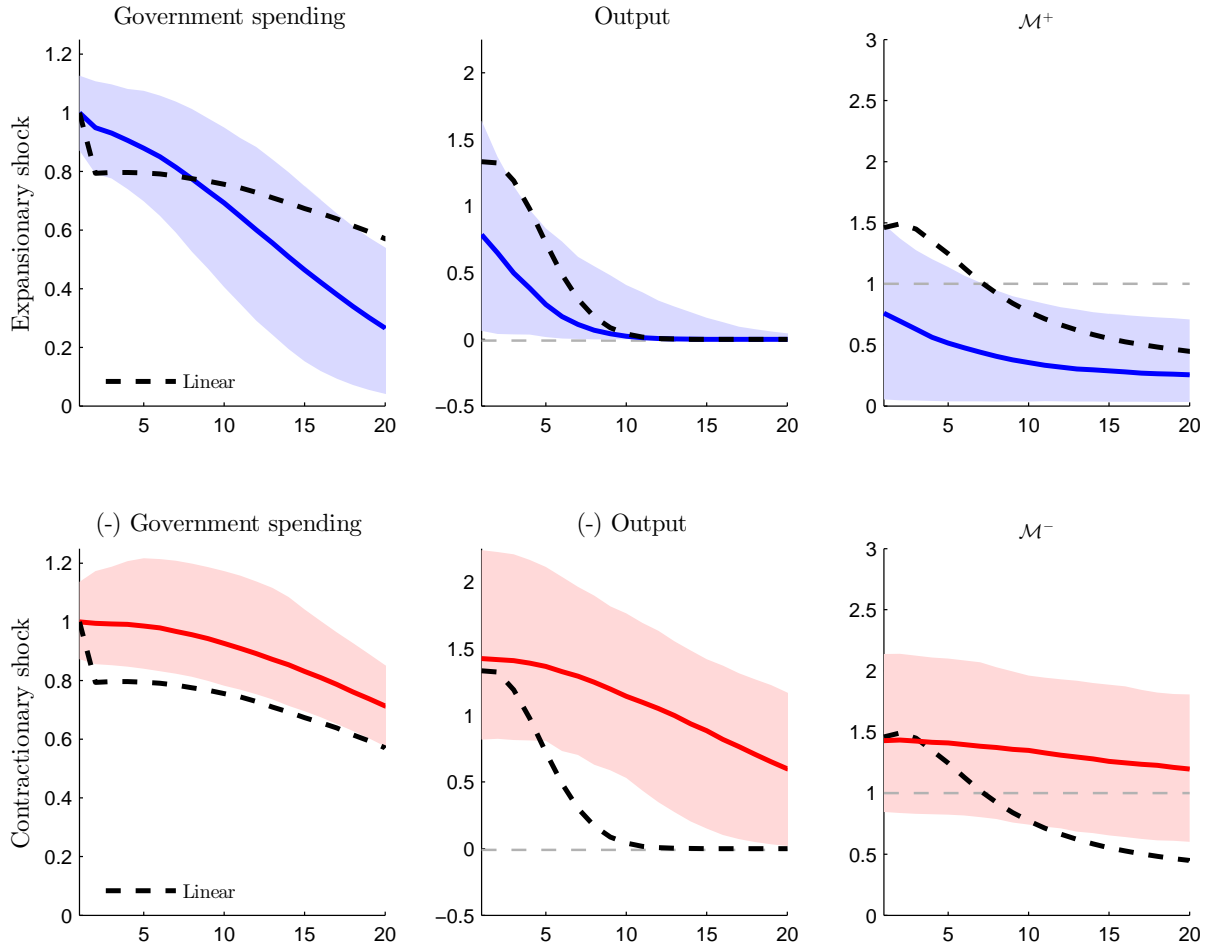


Figure 2: **Recursive identification scheme, FAIR, 1966-2014.** Impulse response functions (in percent) of government spending and output to a government spending shock along with the corresponding multiplier \mathcal{M} . Recursive identification as in Auerbach and Gorodnichenko (2012b). Estimation from a linear FAIR model (dashed line) or from an asymmetric FAIR model (plain line). The thin lines cover 90% of the posterior probability. For ease of comparison between the top and bottom panels, the responses to a contractionary shock are multiplied by -1 in the bottom panels.

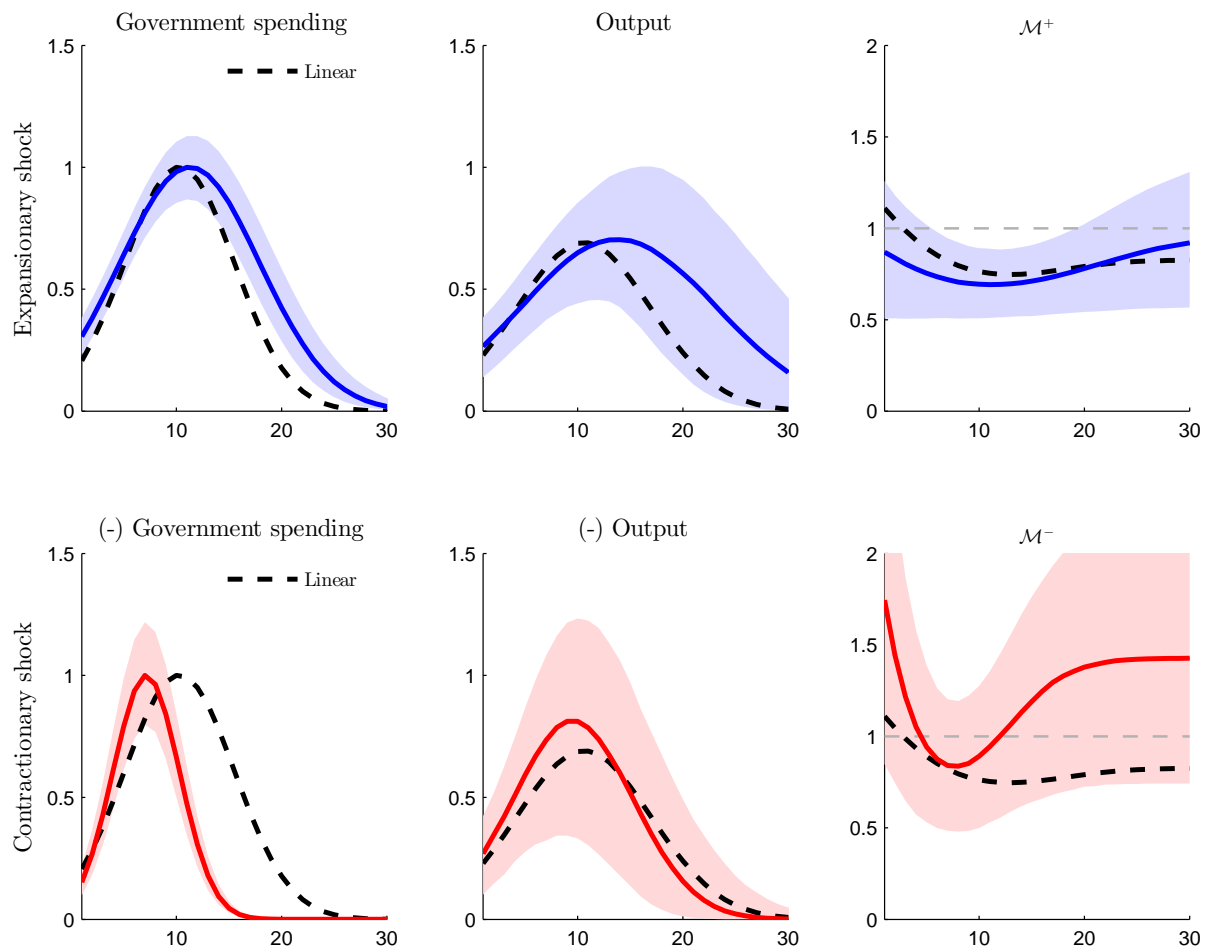


Figure 3: **Narrative identification scheme, FAIR, 1890-2014.** Impulse response functions (in percent) of government spending and output to a news shock to government spending along with the corresponding multiplier \mathcal{M} . Narrative identification as in Ramey and Zubairy (2018). Estimation from a linear FAIR model (dashed-line) or from an asymmetric FAIR model (plain line). The thin lines cover 90% of the posterior probability. For ease of comparison between the top and bottom panels, the responses to a contractionary shock are multiplied by -1 in the bottom panels.

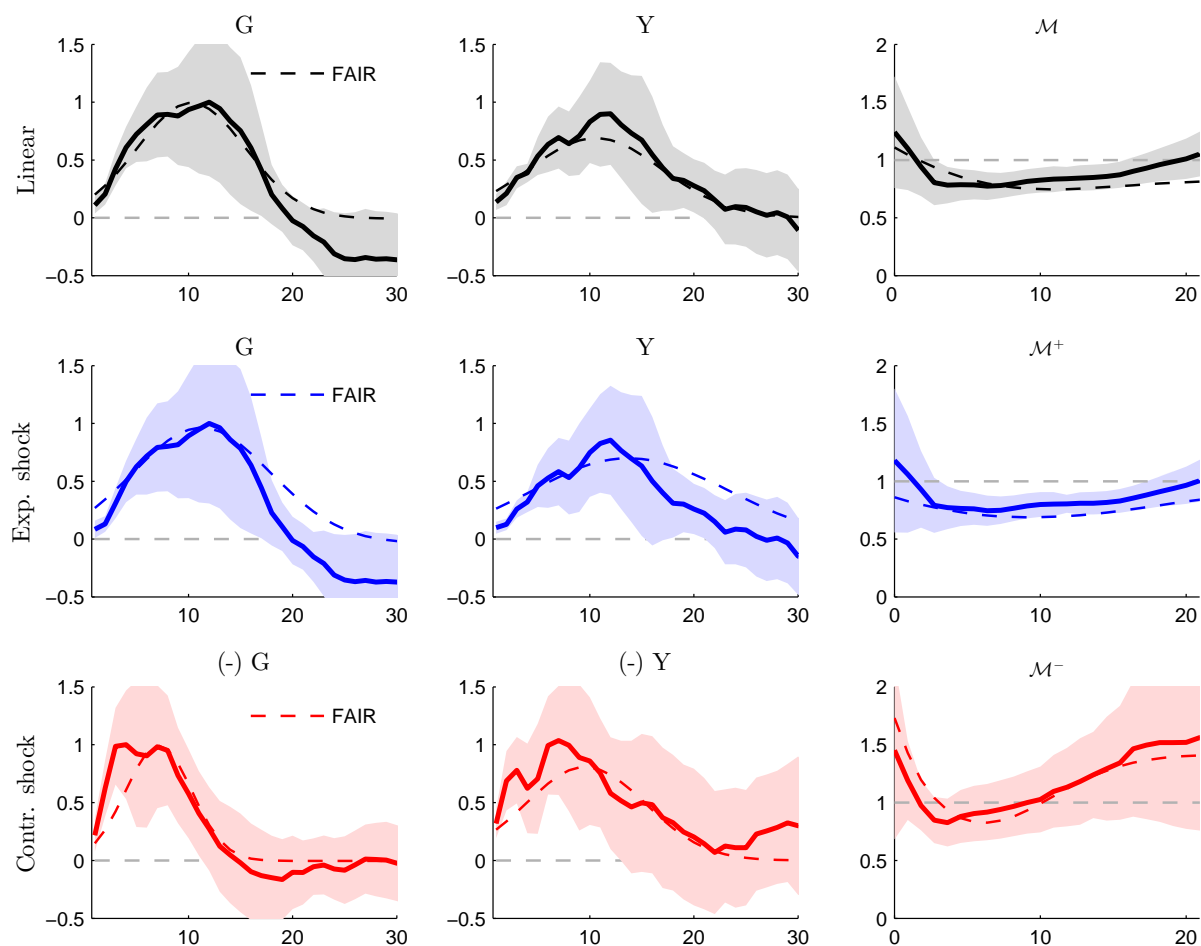


Figure 4: **Narrative identification scheme, LP, 1890-2014.** Impulse response functions (in percent) of government spending and output to a news shock to government spending along with the corresponding multiplier \mathcal{M} . Narrative identification as in Ramey and Zubairy (2018). Responses estimated from a linear model (top row), responses to an expansionary shock (middle row), and responses to a contractionary shock (bottom row). Estimation from Local Projections (plain lines) and from FAIR (dashed-line). The confidence bands denote the 90 percent confidence intervals for the LP estimates. For ease of comparison, the responses to a contractionary shock are multiplied by -1 in the bottom row.

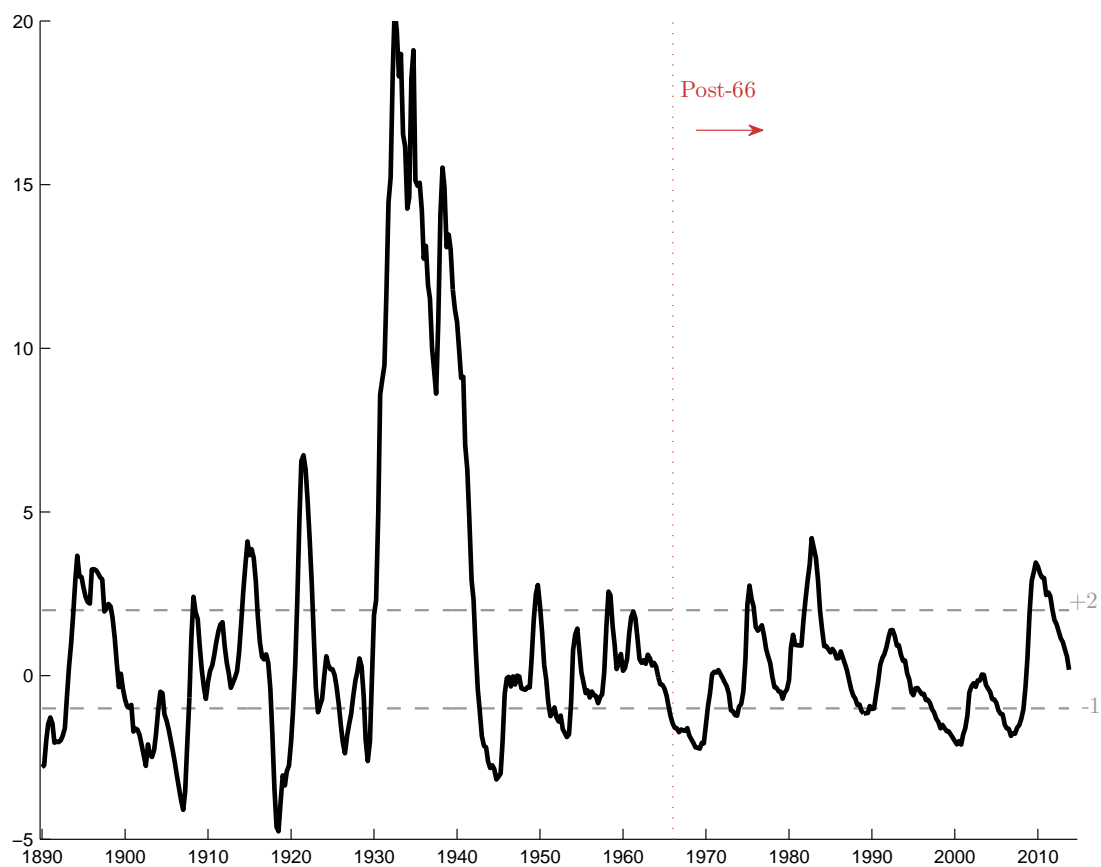


Figure 5: **Business cycle indicator, 1890-2014**: the unemployment rate detrended as in Ramey and Zubairy (2018). The dashed grey lines denote values of the indicator of +2 (“UR high”) and -1 (“UR low”).

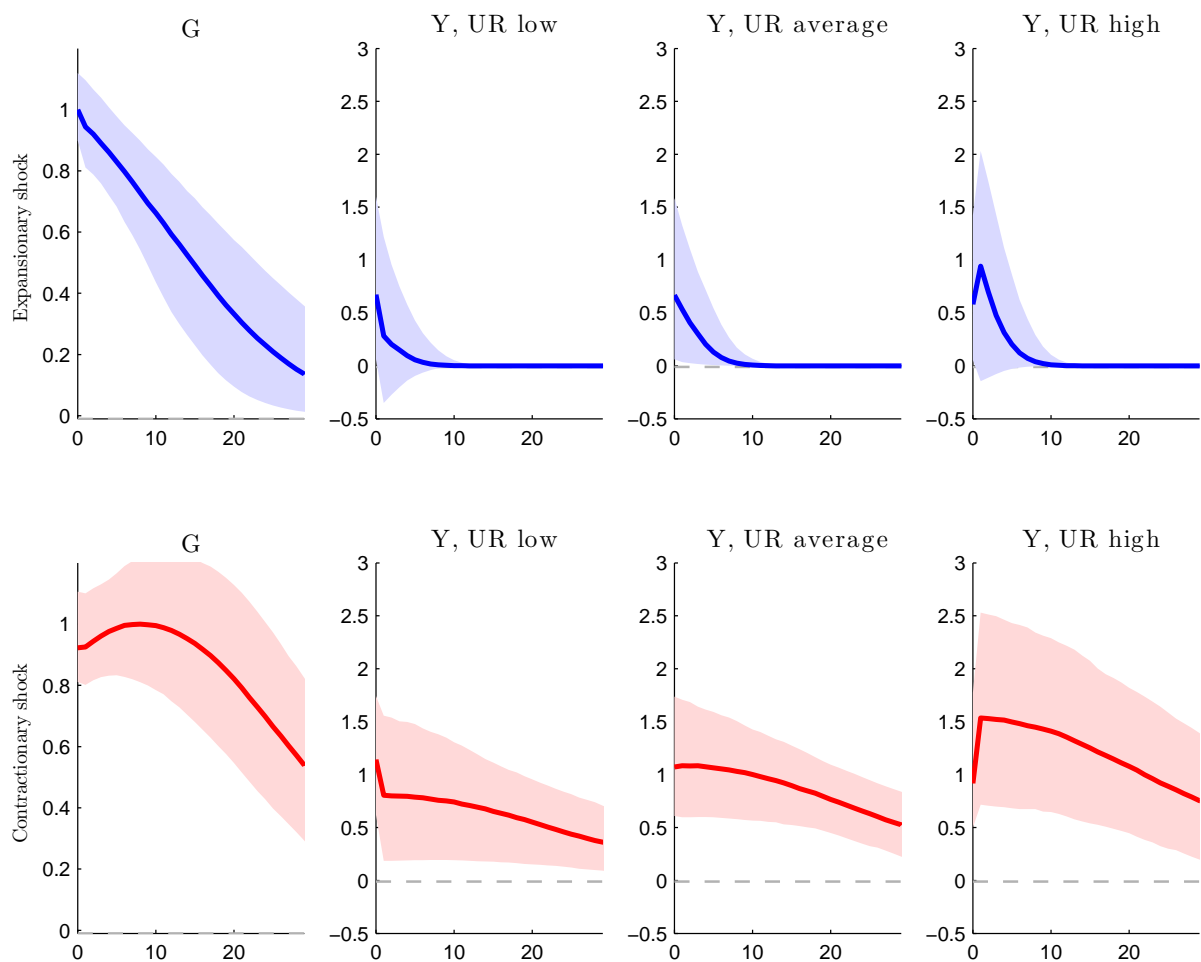


Figure 6: **Recursive identification scheme, FAIR, 1966-2014.** Effect of (detrended) unemployment (UR) on the impulse responses of government spending and output to a government spending shock. “UR high” , “UR average” and “UR low” respectively denotes values of the detrended UR of +2, 0 and -1 . With our modeling of state-dependence (whereby the level of slack only changes the amplitude of the impulse response), the impulse response of government spending, *normalized* to peak at one, is constant. The thin lines cover 90% of the posterior probability. For ease of comparison between the top and bottom panels, the responses to a contractionary shock are multiplied by -1 in the bottom panels.

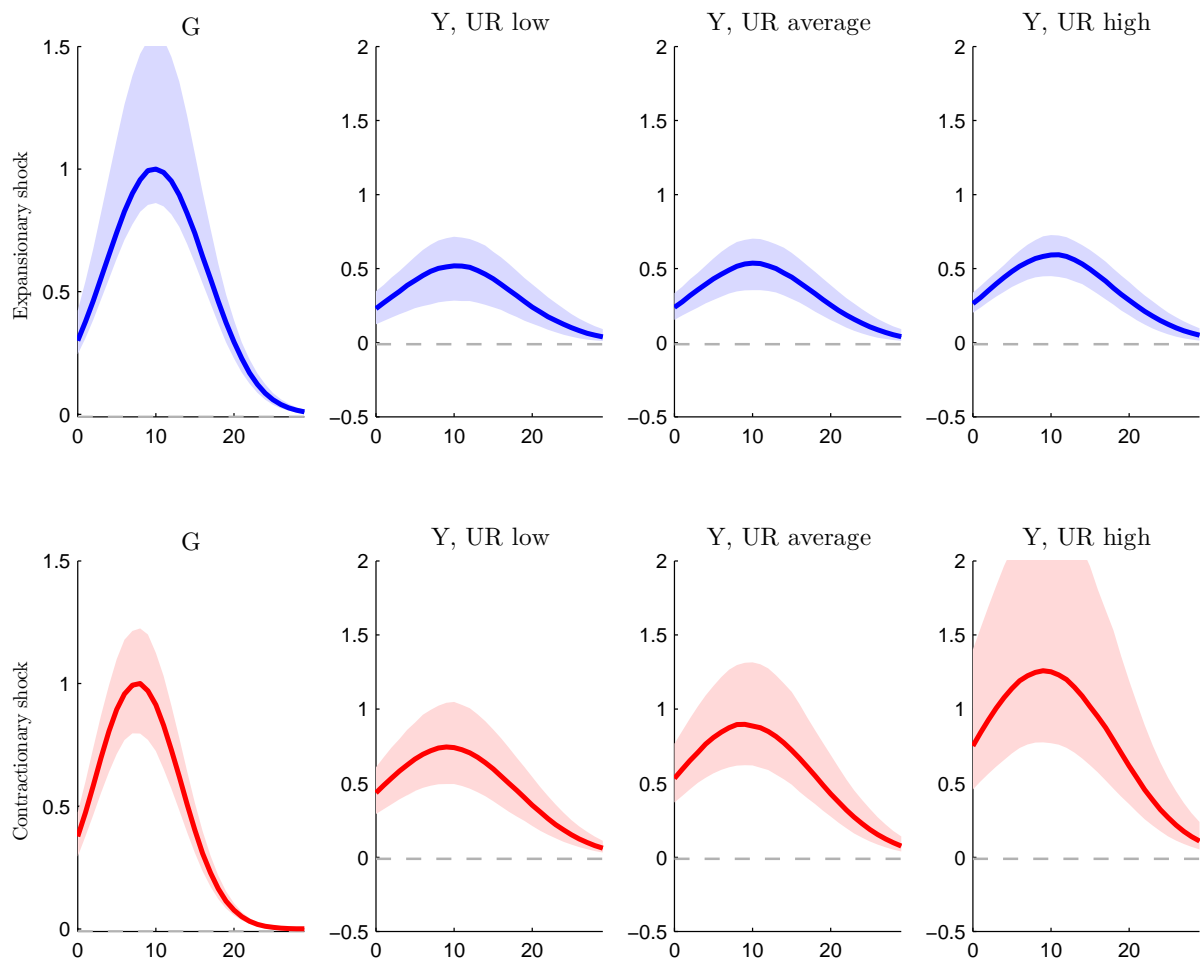


Figure 7: **Narrative identification scheme, FAIR, 1890-2014.** Effect of (detrended) unemployment (UR) on the impulse responses of government spending and output to a government spending shock. “UR high” , “UR average” and “UR low” respectively denotes values of the detrended UR of +2, 0 and -1 . With our modeling of state-dependence (whereby the level of slack only changes the amplitude of the impulse response), the impulse response of government spending, *normalized* to peak at one, is constant. The thin lines cover 90% of the posterior probability. For ease of comparison between the top and bottom panels, the responses to a contractionary shock are multiplied by -1 in the bottom panels.

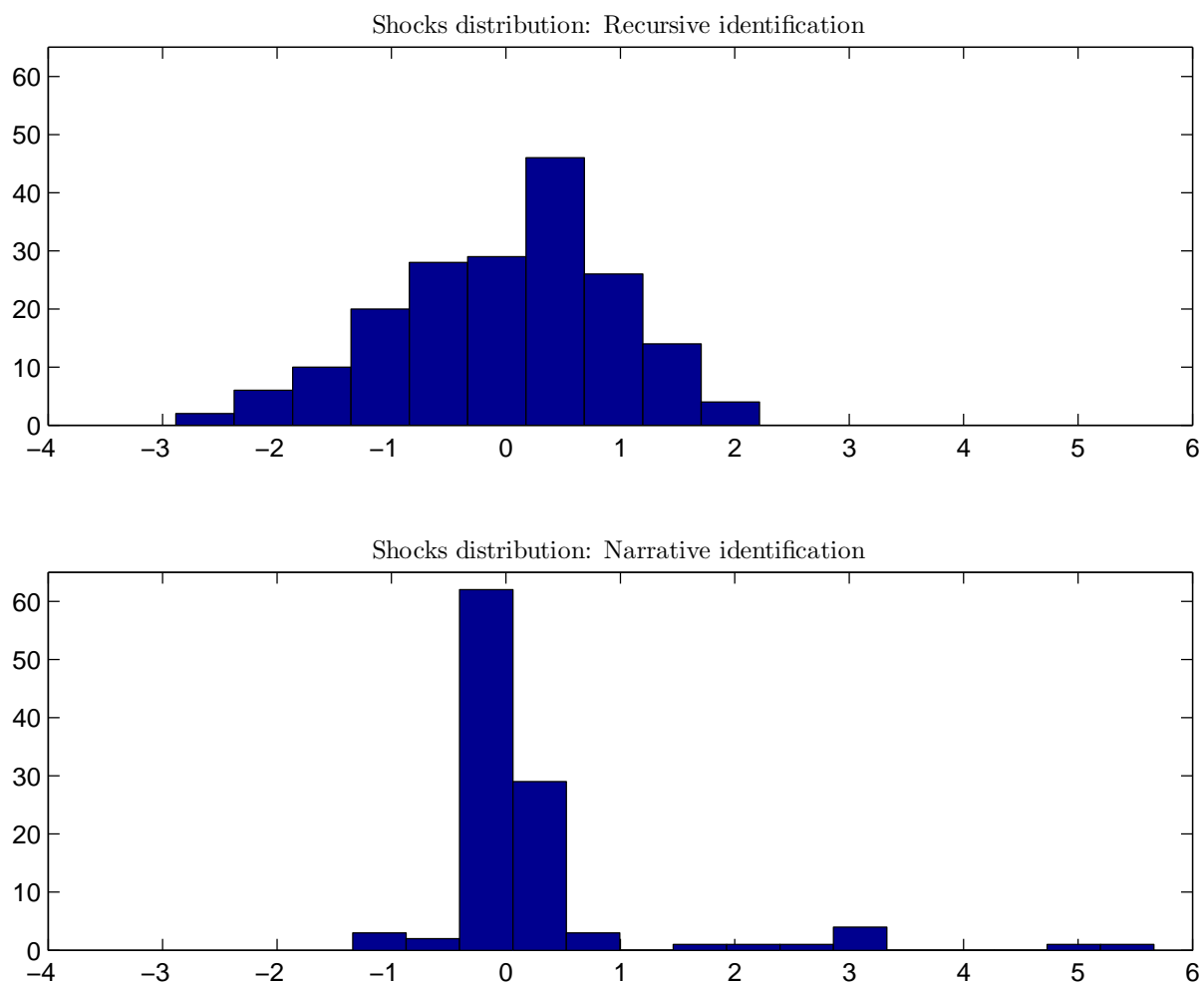


Figure 8: Histograms of the distributions of government spending shocks (rescaled by their standard-deviation). The upper-panel depicts the distribution of shocks recovered from a recursive identification scheme (1966-2014), the bottom-panel depicts the distribution of Ramey and Zubairy (2018) shocks identified from a narrative scheme (1890-2014).

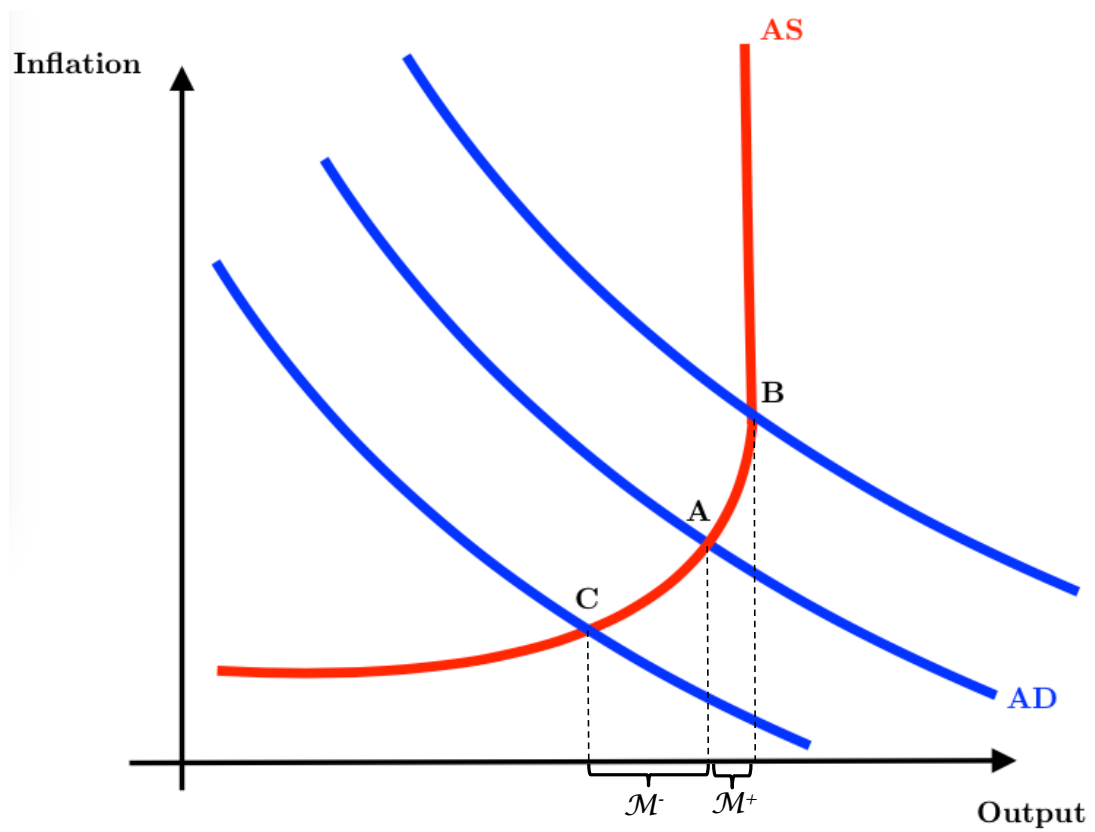


Figure 9: Effects of demand shocks in theoretical model

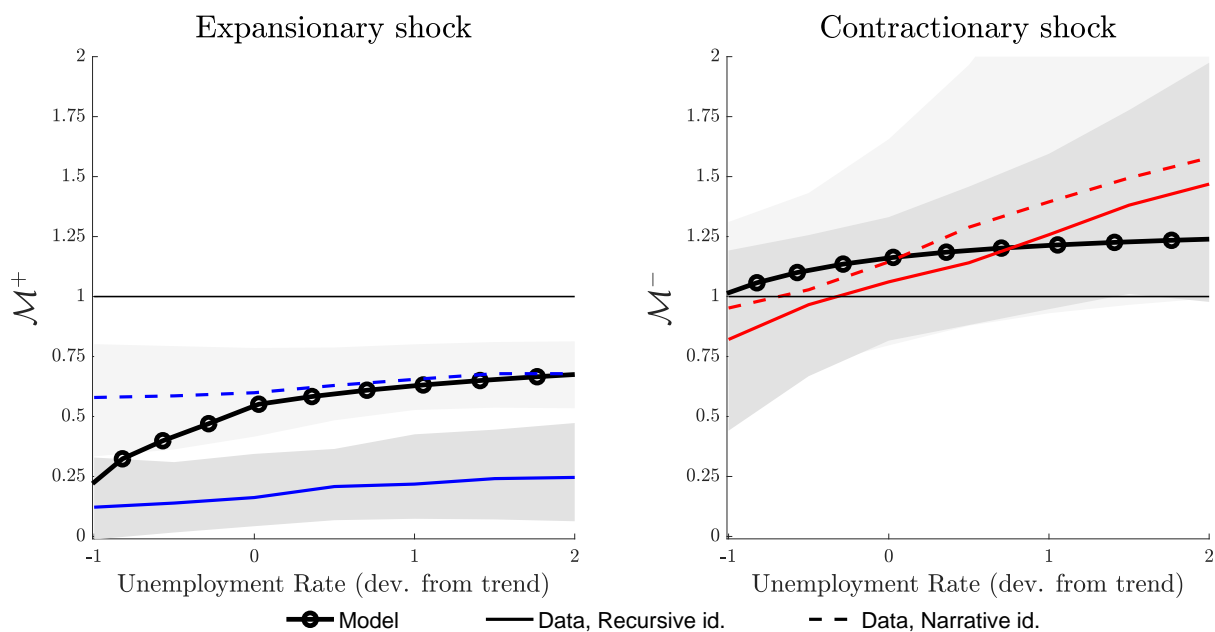


Figure 10: **Fiscal multipliers: simulated model vs. empirical estimates.** The figure plots the government spending multiplier (sum over 20 quarters) for expansionary shocks (left panel) and contractionary shocks (right panel). Each panel reports the values implied by the simulated model (solid line with circles) and the posterior median FAIR estimates, either using the recursive identification scheme (dashed lines), or the narrative identification scheme (solid lines), and where for each case the grey areas denote the 68% posterior probability.

Table 1: Asymmetric government spending multipliers, FAIR estimates

	Linear	Expansionary shock	Contractionary shock
\mathcal{M} (recursive id.) 1966-2014	0.45 (0.2--0.6)	0.27 (0.0, 0.6)	1.25 (0.7, 1.8)
$P(\mathcal{M} > \mathcal{M}^+)$		P=0.98**	
\mathcal{M} (narrative id.) 1890-2014	0.78 (0.6--0.9)	0.76 (0.5, 1.0)	1.36 (0.7, 2.1)
$P(\mathcal{M} > \mathcal{M}^+)$		P=0.96**	

Note: The multiplier \mathcal{M} is calculated by cumulating the impulse responses (IR) over the first 20 quarters. Estimates from FAIR, either with symmetric impulse responses (in black, "linear") or with asymmetric impulse responses (blue and red). Numbers in parenthesis cover 90% of the marginal posterior probability. "recursive id." refers to the Auerbach and Gorodnichenlo (2012) identification scheme. "narrative id" refers to the Ramey and Zubairy (2018) identification scheme). $P(\mathcal{M} > \mathcal{M}^+)$ reports the posterior probability that the contractionary multiplier \mathcal{M} is larger than the expansionary multiplier \mathcal{M}^+ . * and ** denote posterior probabilities above 0.90 and 0.95.

Table 2: Asymmetric multipliers and labor market slack, FAIR estimates

	Expansionary shock		Contractionary shock	
	U low	U high	U low	U high
\mathcal{M} (recursive id.) 1966-2014	0.12 (-0.1, 0.5)	0.28 (0.0, 0.7)	0.85 (0.2, 1.4)	1.46 (0.7, 2.3)
$P(\mathcal{M}^{U \text{ high}} > \mathcal{M}^{U \text{ low}})$	P=0.64		P=0.91*	
\mathcal{M} (narrative id.) 1890-2014	0.58 (0.3, 0.9)	0.68 (0.4, 0.9)	0.95 (0.4, 1.6)	1.56 (0.7, 4.9)
$P(\mathcal{M}^{U \text{ high}} > \mathcal{M}^{U \text{ low}})$	P=0.52		P=0.99**	

Note: The multiplier \mathcal{M} is calculated by cumulating the impulse responses over the first 20 quarters. Numbers in parenthesis cover 90% of the marginal posterior probability. "recursive id." refers to the Auerbach and Gorodnichenlo (2012) identification scheme. "narrative id" refers to the Ramey and Zubairy (2018) identification scheme. $P(\mathcal{M}^{U \text{ high}} > \mathcal{M}^{U \text{ low}})$ reports the posterior probability that the multiplier m is larger in state of high unemployment (detrended unemployment of +2) than in a state of low unemployment (detrended unemployment of -1). * and ** denote posterior probabilities above 0.90 and 0.95.

Table 3: Asymmetric multipliers and labor market slack, 1947-2014

	Expansionary shock		Contractionary shock	
	U low	U high	U low	U high
\mathcal{M} (recursive id.)	-0.00 (-1.2, 0.5)	0.00 (-2.4, 1.5)	1.45 (0.8, 2.1)	2.13 (1.0, 4.5)
$P(\mathcal{M}^{U \text{ high}} > \mathcal{M}^{U \text{ low}})$	P=0.48		P=0.93*	
\mathcal{M} (narrative id.)	0.62 (0.3, 0.9)	0.69 (0.3, 0.9)	0.96 (0.4, 2.0)	1.73 (0.7, 5.4)
$P(\mathcal{M}^{U \text{ high}} > \mathcal{M}^{U \text{ low}})$	P=0.69		P=0.99**	

Note: The multiplier \mathcal{M} is calculated by cumulating the impulse responses over the first 20 quarters. Estimates from FAIR. “recursive id.” refers to the Auerbach and Gorodnichenlo (2012) identification scheme. “narrative id” refers to the Blanchard and Perotti (2002) identification scheme. $P(\mathcal{M}^{U \text{ high}} > \mathcal{M}^{U \text{ low}})$ reports the posterior probability that the multiplier m is larger in state of high unemployment (detrended unemployment of +2%) than in a state of low unemployment (detrended unemployment of -1%). * and ** denote posterior probabilities above 0.90 and 0.95.

Table 4: Multipliers in a Simulated Model

	Expansionary shock		Contractionary shock	
	U low	U high	U low	U high
Baseline	0.21	0.67	1.01	1.24
Perfect Insurance	0.20	0.44	0.30	0.48
Constant Elasticity (AS) curve	0.91	0.91	0.91	0.91

Note: The table reports the values of the multiplier over 20 quarters, both for expansionary (columns 1 and 2) and contractionary shocks (columns 3 and 4). Columns 1 and 3 refer to a case where the economy is initially at a low unemployment state (detrended unemployment = -1%), while Column 2 and 4 the economy is initially in a high unemployment state (detrended unemployment = +2%)