Non-linear effects of government spending shocks in the US. Evidence from state-level data.

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Abstract

This paper uses state-level data to estimate the effect of federal defense spending shocks on state real activity. We find moderately strong evidence that for the average state the fiscal multiplier is larger during recessions. However, there is substantial heterogeneity across the cross-section. The degree of non-linearity in the effect of spending shocks is larger in states that are subject to a higher degree of financial frictions and lower labour market rigidity. In contrast states with a prevalence of mining and agricultural industries tend to have multipliers that are more similar across business cycle phases.

Key words: fiscal policy shocks, non-linearity, structural VAR

JEL codes: C32, E62, R12

1 Introduction

Are the effects of US government spending shocks larger during recessions? A series of recent papers have focussed on this issue but reached quite different conclusions. In an influential earlier contribution Auerbach and Gorodnichenko (2012b) report that government spending multipliers are larger in recessions than expansions. Somewhat weaker evidence for non-linearity is presented in Caggiano *et al.* (2015) who show that differences in spending multipliers manifest themselves when comparing large recessions and expansions but

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are not necessarily apparent when comparing typical recessions and expansions. In a recent paper, Ramey and Zubairy (2014) extend the investigation of non-linearity in a number of directions. One of their key contributions is to use a data set spanning from 1889 to 2013 thus exploiting a substantially larger number of recessions and expansions than previous papers that typically employ time-series starting after the mid-1940s. Based on this extended data, they find no significant difference in the spending multiplier across business cycle phases.

In the spirit of Ramey and Zubairy (2014), this paper investigates the possibility of non-linear effects of spending shocks within an econometric framework that enables the use of a larger number of recessionary episodes than present in a typical time-series. In particular, we follow Owyang and Zubairy (2013) and estimate the impact of military spending on real income of US states. However, our empirical model not only allows this affect to be heterogenous across US states, but also accounts for the possibility that it may differ across recessions and expansions. Crucially, our model enables us to estimate the average effect of spending on state-level real income in recessions and expansions. To the extent that recessions and expansions are not perfectly synchronised across states, this average effect exploits variation across both time *and* cross-sections potentially improving the robustness of the estimates. Our approach thus offers advantages similar to a model estimated using a long-spanning time-series, but mitigates the issues arising from the use of historical data both in terms of quality and the possible effect of structural breaks. However, as we use state-level data our estimates pertain to the spending multipliers for a 'typical' or 'average' US state. Our analysis is thus complementary to papers such as Ramey and Zubairy (2014) that investigates changes in the US-wide spending multiplier.

Our paper makes two key contributions: First, to our knowledge, our paper is one of the first to examine possible non-linearity of the effects of spending shocks at the level of US states. We therefore extend the analysis in papers such as Owyang and Zubairy (2013) who focus on uncovering the linear effect of federal spending on state-level output.[1] This extension is important from a policy perspective. Even if the aggregate impact of spending shocks on US real activity is linear, a large difference in the state-level impact of federal spending in different business cycle phases can be a vital consideration in the policy-making process. Second,

[1] There are several papers that examine the impact of fiscal policy at the level of US states. A prominent recent example is Nakamura and Steinsson (2014). A survey of this literature can be found in Owyang and Zubairy (2013).

from an econometric perspective, we extend the non-linear vector autoregression (VAR) used in papers such as Auerbach and Gorodnichenko (2012b) and Caggiano *et al.* (2015) to a heterogenous panel framework allowing us to estimate the (cross-state) average effect of federal military spending during recessions and expansions.

We find that, on average across states, there is moderately strong evidence that state-level income multipliers are larger during regimes classified as recessions. There appears to be substantial heterogeneity in this degree of non-linearity across states. A regression analysis suggests that this non-linearity is larger in states that are subject to more financial frictions but have flexible labour markets. This result is consistent with the idea that fiscal stimulus during recessions can lead to an 'accelerated' impact on real activity if the negative wealth effects of a rise in government spending are offset by the positive wealth effect on agents that are more acutely affected by the downturn (see Canzoneri *et al.* (2016)). States that have a higher concentration of agriculture may be more likely to receive federal assistance and may be less vulnerable during a recession. Similary, states with a concentration of mining industry may be more influenced by commodity price cycles. We find that these two characteristics are prevalent in states that display a smaller difference in the multiplier across business cycle phases.

The paper is arranged as follows. Section 2 presents the empirical model and describes the data used in the study. The results are presented in section 3 while section 4 concludes.

2 Empirical model and data

We estimate the following non-linear VAR model:

$$\begin{aligned} Z_{it} &= \left(c_{1i} + \sum_{j=1}^{P} b_{1i,j} Z_{it-j} \right) S_{it} + \\ &\quad \left(c_{2i} + \sum_{j=1}^{P} b_{2i,j} Z_{it-j} \right) (1 - S_{it}) + u_{it}, \\ var\left(u_{it}\right) &= \Sigma_{it} = S_{it} \odot \Sigma_{1i} + (1 - S_{it}) \odot \Sigma_{1i} \end{aligned} \tag{1}$$

where $i = 1, 2, ..M$ denotes the data on 50 US states and District of Columbia. In the benchmark model, the matrix of endogenous variables Z_{it} for state i includes the defense spending news shock created by Ramey (2011) (R_t), the log of real federal spending per-capita (G_t) and the log of real personal income per-capita for each state (X_{it}). We also include the sum of income in all states excluding state i, i.e. $F_{it} = \left[\sum_{-i} X_{it}\right]$ as a control to account for possible spillover effects across states (see Owyang and Zubairy (2013)).[2] As is well known in the literature, R_t represents a measure of changes in expected government spending on defense constructed using a narrative approach by Ramey (2011). G_t is defined as a sum of federal investment and consumption and is deflated by the GDP deflator and divided by population. Finally, X_{it} is defined as total personal income in state i deflated by the GDP deflator and divided by population in that state. For most states, the sample runs from 1948Q1 to 2015Q4[3]. After allowing for lags, this leaves us with a total of 13805 observations.

As evident in equation 1, the VAR model features regime switching with the parameters in regime 1 given by $c_{1i}, b_{1i,j}, \Sigma_{1i}$ and those in regime 2 denoted by $c_{2i}, b_{2i,j}, \Sigma_{2i}$. The regime switches are specific to each state and are determined by the regime indicator S_{it} :

$$S_{it} = \frac{\exp\left(-\gamma \tilde{X}_{it}\right)}{1 + \exp\left(-\gamma \tilde{X}_{it}\right)} \tag{2}$$

Following Auerbach and Gorodnichenko (2012b), we define $\tilde{X}_{it}$ as the seven quarter moving average of X_{it-1} once it is standardised and $\gamma = 1.5$. Therefore when $S_{it} \approx 1$, state i is in recession, while $1 - S_{it} \approx 1$ indicates a boom. As discussed in Auerbach and Gorodnichenko (2012b), with this calibration of γ, recessionary episodes make up about 20 percent of the sample period and matches the duration of US-wide recessions in the post-1946 period.

One of the key components of this model is its hierarchical structure. In particular, we assume that the prior distribution for the VAR coefficients $\beta_{1,i} = vec\left([b_{1i,1}, .., b_{1i,P}]\right)$ and $\beta_{2,i} = vec\left([b_{2i,1}, .., b_{2i,P}]\right)$ is defined

[2] As discussed in Owyang and Zubairy (2013) F_{it} accounts for spillovers but imposes that they are equal across states. This may have implications for the response to state-level shocks but does not affect the impact of *aggregate shocks* that are the focus of the current paper.

[3] For some states such as Alaska and Hawaii, income is available only from 1950Q1 onwards.

as:

$$p\left(\beta_{1,i}|\bar{\beta}_1, \lambda_1\right) \tilde{} N\left(\bar{\beta}_1, \lambda_1\Lambda_i\right) \tag{3}$$

$$p\left(\beta_{2,i}|\bar{\beta}_2, \lambda_2\right) \tilde{} N\left(\bar{\beta}_2, \lambda_2\Lambda_i\right)$$

where $\bar{\beta}_1$ and $\bar{\beta}_2$ are the (weighted) cross-sectional average coefficients in the two regimes and Λ_i is set to reflect the scale of the data. The parameters λ_1 and λ_2 control the degree of pooling in the model. As $\lambda \to 0$ the heterogeneity across states declines while $\lambda \to \infty$ implies a completely distinct set of coefficients for each state.

We assume a similar structure for the contemporaneous impact matrices in the VAR. That is, we decompose the error covariance matrices as:

$$\Sigma_{1i} = A_{1i}^{-1} H_{1i} A_{1i}^{-1\prime}$$

$$\Sigma_{2i} = A_{2i}^{-1} H_{2i} A_{2i}^{-1\prime}$$

where A_{1i} and A_{2i} are lower triangular and H_{1i} and H_{2i} are diagonal matrices with shock variances on the main diagonal. A hierarchical prior is assumed for the vectorised non-zero and non-one elements in A_{1i}, A_{2i} (denoted as a_{1i}, a_{2i}):

$$p\left(a_{1,i}|\bar{a}_1, \delta_1\right) \tilde{} N\left(\bar{a}_1, \delta_1\Xi_i\right) \tag{4}$$

$$p\left(a_{2,i}|\bar{a}_2, \delta_2\right) \tilde{} N\left(\bar{a}_2, \delta_2\Xi_i\right)$$

where the weighted cross-sectional averages are denoted by $\bar{a}_1$ and $\bar{a}_2$ and the degree of pooling across states is controlled by the parameters δ_1 and δ_2. The constants c_{1i} and c_{2i} and the shock variances H_{1i} and H_{2i} are allowed to be fully heterogenous across states.

This structure offers two key advantages that are crucial to our study. First and most importantly, the cross-state average impulse response to defense spending shocks in each regime can be estimated using the average coefficients $\bar{\beta}_1, \bar{\beta}_2$ and contemporaneous impact matrices obtained from $\bar{a}_1$ and $\bar{a}_2$. These parameters incorporate information from the panel (and not just from business cycle dynamics in one set of time-series) and are thus likely to be precisely estimated. In particular, across the panel about 2300 observations are classified as recession periods if one defines a downturn as $\Pr[S_{it} > 0.8]$ as in Auerbach and Gorodnichenko (2012b). Second, while our model allows for heterogenous effects of fiscal shocks across US states, the hierarchical prior in equations 3 and 4 implies that the posterior estimates of state-specific impulse responses incorporate information from the panel potentially improving the precision of estimates for individual states.[4]

We confine the details of prior distributions and the MCMC algorithm used for posterior estimation to the technical appendix. However, some key points are worth highlighting. The prior for the variances controlling the degree of pooling λ_1, λ_1 and δ_1, δ_2 is assumed to be an inverse Gamma distribution $IG(s, v)$. As discussed in Gelman (2006) and Jarocinski (2010) the usual 'agnostic prior' with small positive values for s and v can be quite informative in some circumstances. We therefore follow the suggestion in Gelman (2006) and use $v = -1$ and $s = 0$ which implies a uniform prior for the standard deviations. The marginal posterior distributions are approximated using a Metropolis within Gibbs algorithm using 200,000 replications[5]. The technical appendix presents a small Monte-Carlo experiment which indicates that the proposed algorithm performs fairly well.

Following Owyang and Zubairy (2013), the defense spending shock is identified via the recursive ordering: R_t, G_t, F_{it}, X_{it}. This ordering implies that both G_t and X_{it} respond immediately to R_t, an assumption consistent with the regressions used in Ramey and Zubairy (2014). The non-linear impulse responses (based on the average coefficients of the model) are defined as:

$$IRF = E(Z_h | \varepsilon_R) - E(Z_h) \tag{5}$$

where $h = 0, 1, .., 40$ is the horizon and ε_R represents the defense spending shock. The expectations in equation 5 are estimated using Monte-Carlo integration (see Koop *et al.* (1996)).[6] This procedure takes into account the dynamic impact of the shock on the probability of regime switches over the impulse response

[4] Note that this distinguishes our analysis from Auerbach and Gorodnichenko (2012a) who assume no heterogeneity across OECD countries when estimating the non-linear effects of fiscal shocks.

[5] We use a burn-in of 100,000 replications and save every 10th of the remaining draws. The technical appendix presents some evidence in favour of convergence of the algorithm.

[6] Note that $E(Z_h)$ represents the expected future value of the endogenous variables in an average or typical state.

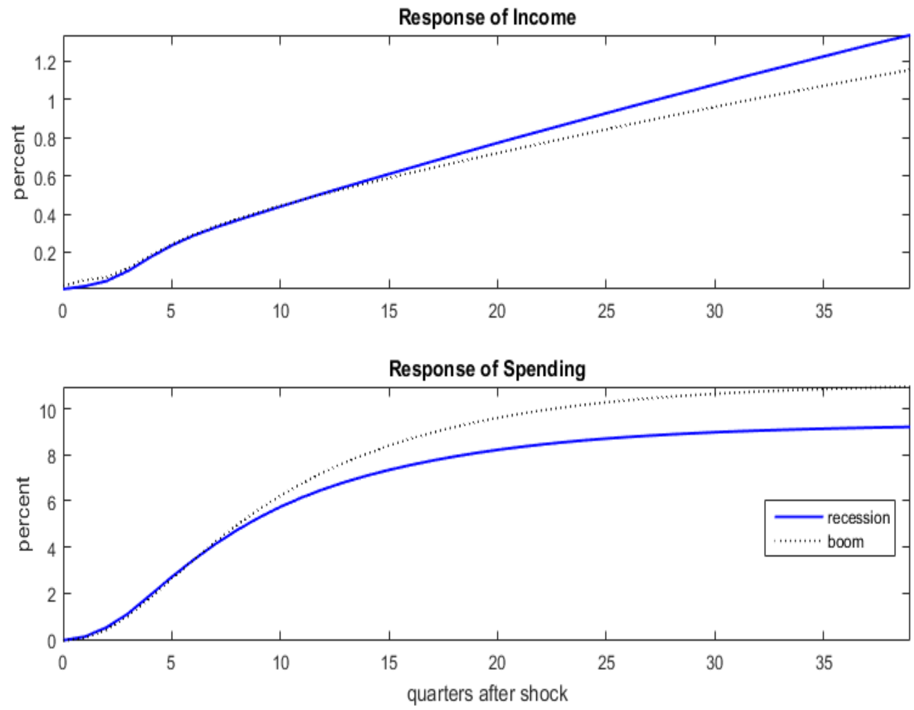

Figure 1: Cumulated response to a defense spending shock

horizon. We compute these impulse responses using two sequence of 'histories' or lagged values of the average state data Z_t as initial conditions: (1) all histories that lie in recessions, i.e. assuming that $S_t > 0.8$ where S_t is computed using the cross-section average of state income. (2) all histories that lie in booms, i.e. when $S_t < 0.2$. As in Caggiano *et al.* (2015), we use these impulse responses to compute (regime dependent) cumulative multipliers of income to defense spending shocks. These multipliers are defined as $\rho \frac{\sum_{h=1}^{H} X_h}{\sum_{h=1}^{H} G_h}$ where H is a chosen horizon and ρ is a scaling factor given by the ratio of average income to average government spending: $\frac{\frac{1}{T}\sum_{t=1}^{T}\left(\frac{1}{51}\sum_{i=1}^{51} X_{it}\right)}{\frac{1}{T}\sum_{t=1}^{T} G_t}$.[7]

Horizon	Recession	Boom
4	3.6 (2.7, 4.7)	3.6 (2.8, 4.1)
8	3.2 (2.6, 3.9)	2.5 (2.1, 2.7)
12	3.2 (2.5, 3.9)	2.2 (1.8, 2.5)
20	3.8 (2.8, 3.9)	2.4 (2, 2.8)
40	6.3 (4.2, 8.3)	3.5 (2.7, 4.6)

Table 1: Spending multipliers. Posterior median with 68 percent HPDI in parenthesis

3 Results

3.1 Results for the average state

We first consider the estimates for a 'typical' or average state based on the posterior estimates of the average parameters of the model. Figure 1 plots the (posterior median) cumulated response to a one unit defense spending shock in recessions and booms. The response of income in both regimes is very similar over the first two years of the horizon. At longer horizons, the impact of the shock is larger in recessions. This difference in the impact of the shock is re-enforced by the estimated response of spending. Two years after the shock, spending increases by a larger amount in booms when compared to recessions. These results suggest, therefore, that for the average state, a defense spending shock is associated with a larger increase in income on the back of a smaller rise in spending, especially over long horizons.

This point is explored more fully in Table 1 and figure 2. The table presents the estimated multipliers in each regime and the 68 percent highest posterior density intervals (HPDI). In terms of magnitude, the multipliers are larger than those typically reported for the US as a whole. As explained by Ramey (2016), multipliers based on state-level data are typically larger than national estimates because accounting for state-specific heterogeneity can remove the influence of taxes that are levied nationally. Over the first two years of the horizon, the estimated multipliers are fairly similar with a clear overlap of the posterior distribution. At longer horizons, the median estimate of the multiplier is larger in recessions, with the difference especially

[7] Ramey and Zubairy (2014) warn against re-scaling in this manner as the ratio of output to spending varies between 2 and 24 over their sample that begins in 1889. In our application (where we use post-1947 data), this variation is less acute with income to spending for an average state between 3 and 10 with a mean of 6.

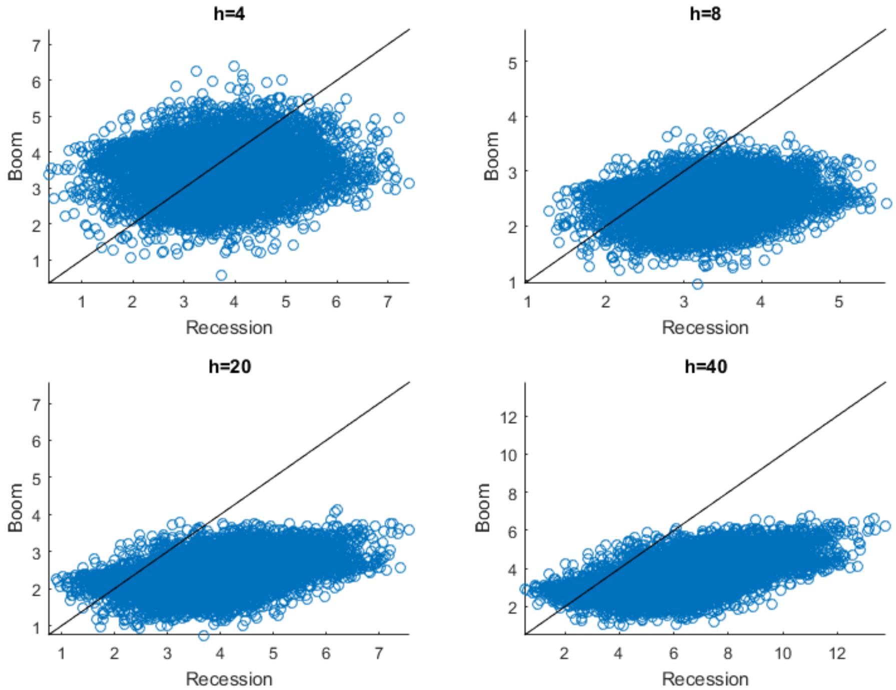

Figure 2: Spending multipliers. Joint posterior distribution. 'h' refers to impulse response horizon.

large at $h = 40$. To consider the statistical significance of this difference across regimes, figure 2 plots the joint posterior distribution of the multiplier in recessions and booms and compares it with the 45-degree line. If the posterior distribution is concentrated on the 45-degree line, then evidence of a systematic difference across regimes is limited.[8] At a horizon of one year, there appears to be no systematic difference in the multiplier across regimes. At longer horizons, however, the joint distribution shifts towards the lower quadrant with the bulk of the points located below the 45-degree line. This provides some evidence that the long-run multiplier in a typical US state is larger in recessions. Note, however, that as a part of the distribution remains on the 45-degree line, we consider this evidence moderately strong in favour of the hypothesis of non-linearity of the impact of spending shocks at medium to long horizons.

3.2 Heterogeneity across states

Oue empirical model provides the impulse response to defense news shocks for each state in the sample. As discussed above, the posterior estimates of state-specific parameters (and thus impulse responses) are based

[8] Cogley *et al.* (2010) use this method to consider the statistical significance of temporal changes in inflation persistence.

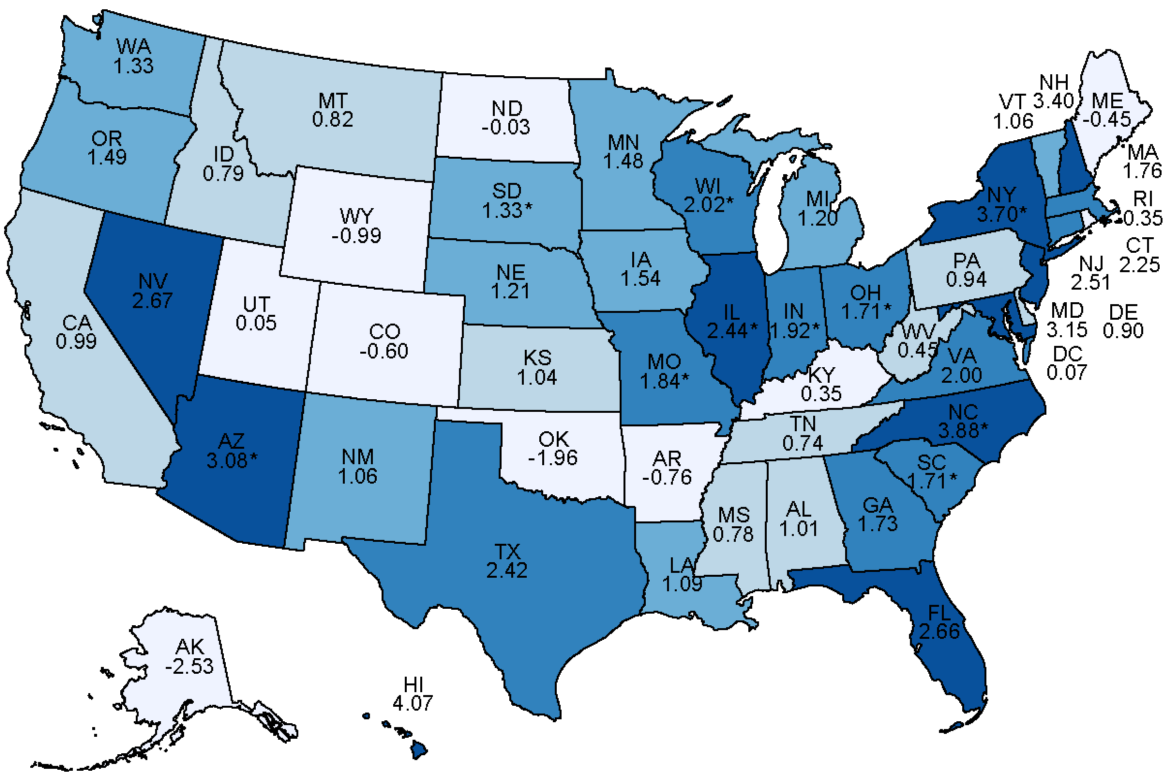

Figure 3: Difference in the multiplier across recessions and expansions at the 20 quarter horizon. The symbol * indicates that the null hypothesis that the multiplier is the same in both regimes can be rejected using the 68% highest posterior density interval.

Variable	Coefficients
Mining	-5.673^{***}
	(1.477)
Agriculture	-9.464^{***}
	(3.073)
Right to work	0.545^{***}
	(0.177)
Small firms	5.115^{**}
	(2.240)
Assistance/subsidies	-28.457^{*}
	(16.58)
Social security	-4.006
	(2.530)
Intergovernmental transfers	1.295
	(1.213)
obs	50
Adj. R^2	0.17

Table 2: Regression results. * p<0.1, ** p<0.05, ***P<0.001. Robust Standard errors in parenthesis. Regional dummies included

on a prior centered at the cross-state weighted average in each regime. Nevertheless, our results suggest the presence of heterogeneity in the degree of non linearity (i.e. the difference in the multiplier in recessions and expansions) across states. This is apparent in figure 3 which displays this information using a heat map. In particular, the figure shows the median difference in the multiplier (at the 20 quarter horizon) between recessions and expansions, with positive numbers indicating that the estimates in recessions are larger. In all but 8 states, the median estimate of the multiplier in recessions is larger. States such as Hawaii, North Carolina, New York, New Hampshire and Maryland top the list with the effect of spending shocks estimated to be much larger during downturns. When the posterior distribution of the multipliers is considered, the null hypothesis that this difference equals zero can be rejected for 11 of these states. Note, however, that the precision of state-specific estimates of the multiplier is likely to be lower than the estimate for the average state considered above in Figure 2. For some states, the impact of spending shocks appears to be larger in expansions. Examples include Alaska, Arkansas, Oklahoma, Wyoming, Colorado and Maine.

The fact that the size and sign of the difference in the multiplier across regimes varies so widely across states begs the question: What factors are responsible for this heterogeneity? We attempt to answer this question by relating the cross-regime difference in the multiplier to a range of state-specific characteristics using the following cross-section regression:

$$\Delta m_i^h = \alpha + \beta X_i + v_i \tag{6}$$

where Δm_i^h denotes the percentage difference in the multiplier in recessions and expansions at horizon $h = 20$. Following studies such as Carlino and Defina (1998), we consider regressors X_i that proxy state-specific characteristics such as the degree of financial and labour market frictions, structure of industry and the fiscal situation of the state. From a theoretical point of view, these characteristics may influence the degree to which fiscal stimulus in recessions is associated with a negative or positive wealth effect. The construction of the data and choice of variables closely follows Carlino and Defina (1998) with a detailed description given in the technical appendix. Here we focus on the characteristics that appear to have the strongest correlation with the dependent variables. This sub-set of preferred regressors is chosen via the leaps-and-bounds algorithm of Furnival and Wilson (1974). Table 2 reports the results from the chosen specification.

Consider the coefficient on the *Small firms*. The share of small firms has been used in previous studies (for e.g. Carlino and Defina (1998)) to proxy for the broad credit channel where small firms are more vulnerable to financial frictions driven by information asymmetries. We find that states that have a larger proportion of small firms tend to have larger multipliers in recessions. This evidence is consistent with the conclusions of Canzoneri *et al.* (2016) who build a model where fiscal stimulus has a larger impact during recessions via its ameliorating effect on financial conditions.

A similar effect appears to be evident for the regressor named *Right to work* which is a dummy variable equalling one for states with right to work legislation. The positive coefficient indicates that states with a lower degree of labour market frictions are associated with a higher value for Δm_i^h. This result is consistent with the argument that states with a more flexible labour market may see their income and employment fall by a relatively larger amount during recessions, with the fiscal stimulus providing a larger benefit in recessions when compared to other states.

There is some evidence suggesting that states that receive more government subsidies (*Assistance/subsidies)* tend to have a smaller difference in the multiplier in recessions and expansions. Government subsidies may alleviate the negative effect of recessions and reduce the effectiveness of any positive wealth effects generated by the fiscal stimulus. The share of mining in state nominal GDP (*Mining*) and the share of agriculture in state nominal GDP (*Agriculture*) have a negative and significant impact on Δm_i^h. States with a large agricultural sector may be more likely to receive federal aid (see Owyang and Zubairy (2009)). If this is the case, then the positive effects of fiscal expansion during recessions may be smaller. Similarly, Mumtaz *et al.* (2016) report that increases in uncertainty (that usually accompanies recessions) tends to have a smaller negative effect on states with a larger mining sector thus reducing the need for fiscal stimulus. Moreover, a concentration of mining industry may make the state more dependent on the price of commodities that may not necessarily be procyclical.

In terms of magnitudes, a 1 percentage point increase in the share of small firms is associated with a nearly 6 percentage point rise in the multiplier in recessions relative to expansions. Labor market frictions are less closely linked, with a coefficient nearly ten times smaller. Industry structure has the largest effects. A 1 percentage point higher agricultural share is associated with a more than 10 percentage point smaller difference in multipliers over the cycle.[9]

3.3 Robustness

We carry out an extensive sensitivity analysis to check the robustness of the results. A summary is provided in this section with detailed results reported in the technical appendix. First, we change the ordering of the defense spending shock making it the last variable in Z_{it}. The top panel in Table 1 in the technical appendix shows the estimated average state multipliers. While the magnitude of the mutipliers is lower due to zero restrictions implied by this ordering, evidence in favour of non-linearity is evident – the estimated multiplier is larger during recessions. The second panel of this table shows a version of the benchmark model where the three month treasury bill rate is added as an additional endogenous variable, ordered last to account for monetary policy. Again, the estimated average multipliers are similar to the benchmark case. The estimates are imprecise when federal taxes are added to the model (and placed before X_{it}) but are qualitatively similar to the benchmark case. The posterior medians suggest the presence of negative long-run multipliers during

[9]Explanatory variables that cannot account for any differences in multipliers beween booms and recessions at the state level include the fiscal situation, such as tax revenue as a share of expenditures, as well as the deficit and debt.

booms, while this estimate is positive during the recession regime. The second to last panel in Table 1 shows that adding a time trend to the benchmark specification does not alter the main conclusions, with the multiplier estimated to be larger in recessions. The final panel in Table 1 re-estimates the benchmark model assuming that γ equals 10 implying that regime shifts are abrupt. The estimated multipliers in the recession regime are also larger in size in this specification providing support for the benchmark. Finally, Table 2 in the technical appendix re-estimates the cross-section regression in equation 6 using the difference in the multiplier calculated at horizons 12 and 40. These results are very close to the benchmark estimates shown in Table 2.

4 Conclusion

This paper investigates if the impact of defense spending shocks on the real income of states is larger during recessions. For this purpose, we employ a non-linear VAR model that allows us to exploit the panel dimension of the data set. Thus our estimated regime dependent impulse responses are based on substantially more information than a pure time-series model. The estimated multipliers for the average state are larger in recessions at medium to long horizons. There is moderately strong evidence that this difference is systematic, with the joint posterior distribution of the multiplier in the two regimes 'skewed' more towards recessions. When we estimate the regime dependent multiplier for each state, we uncover a large degree of heterogeneity. The multiplier is larger in recessions for states that are subject to credit frictions, but have more flexible labour markets. In contrast, characteristics that ameliorate the severity of downturns appear to reduce the degree of non-linearity in the impact of fiscal expansion.

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