The Government Wage Bill and Private Activity

Dimitrios Bermperoglou * Evi Pappa† Eugenia Vella ‡

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Abstract

We estimate the macroeconomic effects of public wage expenditures in U.S. data by identifying shocks to public employment and public wages using sign restrictions. We find that public employment shocks are mildly expansionary at the federal level and strongly expansionary at the state and local level by crowding in private consumption and increasing labor force participation and private sector employment. Similarly, state and local government wage shocks lead to increases in consumption and output, while shocks to federal government wages induce significant contractionary effects. In a stylized DSGE model we show that the degree of complementarity between public and private goods in the consumption bundle is key for explaining the observed heterogeneity.

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*University of Lausanne, e-mail: dimitrios.bermperoglou@unil.ch
† *Corresponding author*, European University Institute, Florence 50133, Italy. Tel.: +39 055 4685908, e-mail: evi.pappa@eui.eu
‡University of Sheffield, e-mail: e.vella@sheffield.ac.uk

1 Introduction

The last financial crisis and the subsequent Great Recession still take their toll on many advanced economies. They have posed a serious threat on output and the labor markets, leading to an unusually slow recovery. This fact has revived the debate on the effectiveness of discretionary fiscal policy as a tool to stimulate private activity, establish sustainable growth and recover lost jobs. Another relevant question that naturally arises in this context is which fiscal instruments are the most effective for fueling economic activity.

Most of the empirical VAR literature on the macroeconomics of fiscal policy does not distinguish between different types of government spending, and treats total government spending as a single fiscal instrument. Needless to say, not all types of government spending are expected to induce the same effects on the macroeconomy. Furthermore, most of the literature interprets the empirical effects of this total government spending instrument as if they were the result of changes in government consumption of goods and services. However, government spending is not only consumption of goods and services. Wage and salary payments account for a large share of public expenditure in the U.S. During the postwar period, government wage and salary expenditure has accounted for about 50% of government expenditure (See Figure 1(b)). In the aftermath of the Great Recession, concern about the government budget has focused greater attention on the costs that the government incurs to compensate its employees.

Given the weight of wage expenditures in total government spending, the purpose of this paper is to estimate the effects of public wage bill policies on output and the labor market of the private sector, and draw policy implications that could be useful in the aftermath of the crisis. Using U.S. data over the period 1979-2007, we identify exogenous shocks to public employment and public wages. Following Mountford and Uhlig (2009), we adopt an agnostic identification that sets a minimum set of sign restrictions to the fiscal shocks identified. In particular, we identify shocks to government employment that raise government employment for four quarters and shocks to government wages that induce an increase in the average hourly wage rate for four quarters after the shock. We also ensure that the identified shocks to the government wage bill are orthogonal to business cycle, monetary policy, and government revenue shocks.

In a spirit similar to Ramey (2012), we ask whether the two shocks differ in their ability to stimulate private activity, raising employment and lowering unemployment. Our findings indicate that the effects of government employment shocks are clearly expansionary at the state and local (S&L henceforth) level, and only mildly expansionary at the federal level, while shocks to the government wage rate can be contractionary at the federal level and expansionary at the

S&L level. Shocks to S&L government wages and employment lead to a crowd in of private consumption, while shocks to federal government wages lead to public-private wage spillovers, inducing a negative labor demand effect, a sharp fall in private sector employment and an increase in unemployment.

The existing literature is silent about the effects of shocks to the government wage bill on private economic activity. Apart from Linnemann (2009) that has demonstrated in aggregate U.S. time series that increases in government employment generate positive responses of private employment and real output and a short-lived expansion in private consumption, and Pappa (2009) that has reported mixed results for the employment response to government employment shocks using annual U.S. state and aggregate data over the period 1969-2001, very few papers study the effects of changes in the government wage bill. Moreover, we expand the existing literature by (i) disentangling the effects of shocks to both public employment and public wages; (ii) disaggregating the effects by government level; (iii) examining the effects on the labor force participation and unemployment rates.

In order to explain the empirical findings, we develop a Dynamic Stochastic General Equilibrium (DSGE) model with sticky prices augmented with public good production, allowing for both productive and utility-enhancing services for the public good, search and matching frictions, and endogenous labor force participation Our theoretical model matches qualitatively the empirical evidence for all shocks considered in the empirical exercise. More specifically, public employment shocks are expansionary by crowding in private consumption and increasing labor force participation and employment in the private sector. In the standard neoclassical growth model, increases in public employment should reduce private consumption and private employment as the additional labor supply spurred by the fiscal shock's negative income effect is entirely absorbed by the public sector (see Finn (1998)). We show that the complementarity of the public good with private consumption in the aggregate consumption bundle of the household can overturn the negative wealth effect of the shock and lead to an increase in private consumption. Our findings confirm, in a different framework, the results of Linnemann (2009) who shows that if public services are complementary to private consumption goods in the household's utility function, an increase in public employment raises private consumption and private sector employment.[1] Also in a similar framework to ours, Forni et al. (2009) demonstrate that shocks to public employment can lead to increases in private consumption

[1] This mechanism when combined with mild increasing returns and variable capacity utilization is shown to also explain initially positive (though later on negative) responses of investment and real wages to public employment shocks that seem to be consistent with Linnemann's (2009) empirical evidence.

in a model with rule of thumb consumers.[2] In their model, there is also a positive covariation between public and private employment, since the additional consumption demand makes private sector firms, which are demand constrained, expand their labor input to meet the increase in aggregate demand. Here, we study the effects of both public employment and public wage shocks and provide an alternative mechanism which rests on the complementarity channel rather than liquidity constrained households, and it is able to explain the transmission of both types of shocks.

Our model also explains how government wage shocks can be contractionary or expansionary at the different government levels. More specifically, wage shocks lead to public-private wage spillovers, inducing a negative labor demand effect, a sharp fall in private employment, and an increase in unemployment. At the same time, they can lead to a crowd in of private consumption given the complementarity of the latter with the public good in the aggregate consumption bundle of the household. These two opposite channels can help explain the empirical results. For sufficiently high degree of complementarity between the public good and private consumption in the aggregate consumption bundle, our model predicts positive effects of government wage shocks on private activity, as found for S&L government wages in the data. On the other hand, when the complementarity channel is weaker, the wage spillover effect in the private sector dominates, leading to a substantial fall in private employment and a short-run contraction in private activity. To examine the sensitivity of our conclusions, we perform a sort of prior predictive analysis (see e.g., Leeper et al. (2015)). The analysis reports the probability distribution of impulse responses that the model can produce. The model with low degree of complementarity between public and private goods can generate negative output responses for government wage shocks and small multipliers for government employment shocks, while for strong complementarity between the private and the public goods the model can generate positive responses for wage shocks and higher multipliers for employment shocks. We conclude that the degree of complementarity between private and public goods is key for explaining the observed heterogeneity of responses in the different government levels.

Our analysis therefore suggests that the public good provided at the federal level may exhibit a different degree of complementarity with private consumption than that at S&L level.

[2] The response of private consumption following total government spending shocks has received much attention in the literature. Deep habits or rule-of-thumb consumers have been shown to generate consumption crowding in (e.g., Ravn et al., 2006 and Gali et al., 2007), whereas another class of models includes government investment as part of the production function (Leeper et al., 2010, Drautzburg and Uhlig, 2015). Monacelli et al. (2010) show that a combination of consumption-leisure complementarity in household's preferences and New Keynesian features can generate consumption crowding in a model with search and matching frictions.

This might be justified by the different nature of the public good provided in each case. For instance, federal government employees largely comprise military and defense employees, while S&L government employees provide mainly education, health care and transportation services. Research by Fiorito and Kollintzas (2004) using European data has indeed shown that the degree of complementarity between government and private consumption is not homogeneous over types of public expenditures. In particular, 'merit' goods, including health and education, complement private consumption, while 'public' goods, referring to defense, public order and justice, are substitutes with private consumption. This idea is in line with recent work by Perotti (2014) who shows that defense spending shocks in a SVAR generate contractionary responses, while civilian government spending shocks generate large expansionary responses. The theoretical explanation provided in that paper is based on the assumption that civilian spending exhibits Edgeworth complementarity with private consumption, while defense spending is not utility enhancing. In a similar vein, Pieroni and Lorusso (2015) present VAR estimates for the U.S. economy showing that civilian expenditure induces a positive response of private consumption, whereas military spending has a negative impact. Our results square well also with the evidence presented in Bouakez and Rebei (2007) who, using a maximum-likelihood estimation with U.S. data, find a strong Edgeworth complementarity between the two types of consumption goods. Also, Fève et al. (2013) show that government spending multipliers obtained in the literature may be downward biased because the standard approach does not allow for complementarities between private consumption and government spending in the utility function.

Our work has a number of useful policy implications in the aftermath of the crisis and the slow recovery in advanced countries. In particular, increases in public employment can stimulate the private sector's employment, encourage labor force participation and private demand. On the other hand, public wage policies could be expansionary only if the increases in wages are associated with the production of those public goods that strongly complement private consumption. Wage increases should target, for instance, employees that work in public education or the public health system.

The outline of the paper is as follows. The next section describes the data on the U.S. government wage bill and public employment, the estimated VAR model and empirical findings. Section 3 presents our theoretical model which matches qualitatively the empirical evidence. Finally, Section 4 concludes.

2 Empirical analysis

2.1 Data

As shown in Figure 1(a), since the 1970s public wage expenditures have accounted for around 50% on average of government expenditures in the U.S. and around 5% of GDP. Although the literature has looked extensively at the macroeconomic effects of certain components of U.S. government spending, such as public investment, research on the effects of the public wage bill has been surprisingly limited, despite the fact that it represents the largest component of spending, as shown in Figure 1(b). Looking at a decomposition of public wage expenditures by government level, we see a shift over time towards states and localities, with the federal share amounting to between 20% and 30% from the 2000s (Figure 1(c)). In 1980, federal civilian employees made up 2.3% of the workforce, while they accounted for 1.7% of the workforce in 2010 ((Falk (2012)). According to the same authors, for the past 30 years, the number of civilians employed by the federal government has fluctuated around 2 million people. Besides federal civilian workers, the armed services include steadily more than 2 million uniformed personnel.

In order to take a view of the variation in the government wage bill, in Figure 2 we plot the quarterly growth changes in the two basic components of the wage bill: government employment and the average real hourly wage in the public sector. Government employment is defined as the number of government employees per capita, including both civilian and military employees. Data on civilian employees comes from the Bureau of Labor Statistics, while the military employees series is constructed by Ramey (2011). The average real hourly wage is constructed using the NBER extracts of the CPS Merged Outgoing Rotation Groups. We construct quarterly series for hourly wages at the federal and the S&L government level, and also for the private sector, by regressing for the repeated (monthly) cross section the log of hourly wage – separately for each of the two categories – on socio-demographic variables (age group, gender, race, and marital status) and dummies for each state in order to adjust for worker quality and composition of the workforce. Monthly residuals are transformed to quarterly observations using the mid-quarter residuals estimates and are de-seasoned and deflated using the GDP deflator series. We exclude from the sample workers that have never been employed full time and self-employed individuals.[3]

[3]Ideally, we would have liked also to control for educational attainment. However, there is a break in the educational attainment series between December 1991 and January 1992 because of the revised questionnaire

As can be readily seen, the various fiscal episodes (i.e. unusually large changes in the spending components) are not correlated. Those fiscal episodes can be related to several policy episodes in history. In particular, the data point to a significant increase in federal employment in 1990, when President Bush increased government employment for defense in the face of the German reunification, and to a fall in public employment in 1980, after Reagan won the presidential election and cut the Comprehensive Employment and Training Act of 1974. The series of hourly wage changes track well the amendments of the Minimum Wage Rates Under the Fair Labor Standards Act, 1938-2009.[4] According to the U.S. department of Labor, in 1990 a minimum wage increase occurred for all covered, nonexempt workers. The Minimum Wage Rates Under the Fair Labor Standards Acts of 1996 and 1997 increased the minimum wage for all covered, nonexempt workers. The significant change in government wages observed in 2007 could be related to the Fair Minimum Wage Act of 2007, a U.S. Act of Congress that amended the Fair Labor Standards Act of 1938 to gradually raise the federal minimum wage from $5.15 per hour to $5.85 per hour. When we compare the series at the federal and the S&L level, many striking differences in the employment and wage growth series emerge. For example, the increases in federal employment in 1990, and again in 2000, were accompanied by a fall in S&L employment at the same time period. For the wage series, we observe a big fall in the growth rate of hourly wages at the federal level in 1997, while, on the other hand, we observe a big surge of S&L government wages after 1985 and in 2007, with federal wage growth being around the trend in this period.

2.2 The VAR model

In this subsection, we formalize the econometric framework in order to estimate the short-run effects of public employment and wage shocks on private activity. We consider a VAR model of eleven endogenous variables. We first include the four main items of government spending: the log of government employment per capita, the log of average real hourly public wage, the log of real per capita government expenditure in goods purchases, defined as government consumption minus compensation of government employees, and the log of real per capita gross fixed investment. The second set of seven variables included in the VAR are: the log of real per capita net (of transfers) tax revenue, the log of real per capita private GDP, private

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and we were not able to harmonize the data. Also, we would have preferred to deflate using state-level data on GSP deflators, but we were constrained to use aggregate GDP deflator series due to data availability.

[4]See U.S. Department of Labor: 'History of Federal Minimum Wage Rates Under the Fair Labor Standards Act' at https://www.dol.gov/whd/minwage/chart.htm.

consumption and private investment, the inflation rate, a measure of short-term interest rate and a labor market variable. The latter alternates between (i) the log of private employment per capita, (ii) the real private wage rate, (iii) the unemployment rate, and (iv) the labor force participation rate. Finally, we include in the VAR an exogenous war dummy variable with several lags to control for strong anticipation effects (see Ramey (2011)). Following Uhlig (1994) and Mountford and Uhlig (2009), we do not include any constant or time trend.[5]

The type and number of variables included in the VAR is mainly dictated by the identification scheme we use in order to identify government employment and wage shocks, as described in the next subsection. The fact that we seek to uncover the effects of fiscal shocks on the private economy is another reason that orientated us towards considering private sector's measures of most variables. The output variable, for instance, refers to an approximation of the value added produced by the private sector, which equals total GDP net of the government wage bill (according to the definition of 'Private Sector Production' in Ramey (2012), Figure 1). The exclusion of the government wage bill also allows us to isolate the second-round effects of public wage expenditures on output, net of the direct impact of the public wage bill on GDP.

According to information criteria, we set the lag length of the VAR to two. Following Uhlig (2005), we carry out a Bayesian estimation using flat priors on the coefficients of the model and the covariance matrix of the shocks (see Appendix B). We use quarterly, seasonally adjusted data for the U.S. from 1979 to 2007. The starting period is mainly dictated by the availability of the public wage series, while the sample stops in 2007 in order for our results not to be biased from extraordinary economic conditions (e.g. interest rates close to the zero lower bound, financial crisis etc.). We estimate the effects of spending policies by government level: federal and S&L. Hence, the VAR exercise is repeated twice, using government expenditure series for each government level. The series come from the Bureau of Economic Analysis, the Bureau of Labor Statistics and other sources. A detailed description of the data is provided in Appendix A.

2.3 Identifying the shocks

We base the identification of the fiscal shocks on the sign restriction approach (Arias et al. (2014), Canova and Pappa (2007), Mountford and Uhlig (2009), Pappa (2009), Uhlig (2005)).

[5] As the authors discuss, this is important to obtain more robust results because of the interdependencies in the specification of the prior between these terms and the roots in the autoregressive coefficients. However, we have also estimated a VAR including a constant and a quadratic trend. The results remain qualitatively robust and are available in the online Appendix.

The use of sign restrictions avoids, in principle, typical problems associated with the identification of economically meaningful fiscal shocks. In particular, problems concerning the scarceness of reasonable zero-identifying restrictions are to a large extent avoided. Hence, we opt for an agnostic identification that sets a minimum set of sign restrictions on the responses to the fiscal shocks and, at the same time, controlling for the business cycle or other macroeconomic shocks.

Similarly to Mountford and Uhlig (2009) and Arias et al. (2014), we perform a sequential shock identification. We first identify a generic business cycle shock that implies a positive co-movement of output, private consumption, private investment and government revenue for four quarters $k = 0, 1, 2, 3$. According to some methodological advances in the empirical literature (Arias et al. (2015)), we identify a monetary policy shock by imposing two sets of restrictions on the structural representation coefficients of the interest rate equation, which can be thought as an approximated Taylor rule equation. In particular, we require that (i) the federal funds rate is the monetary policy instrument and it only reacts contemporaneously to output and prices, and (ii) the contemporaneous reaction of the federal funds rate to output and inflation is nonnegative.[6] We also require the monetary policy shock to be orthogonal to the business cycle shock.

After identifying the business cycle and monetary policy shock, we turn to the identification of the fiscal shocks. In particular, we recover sequentially a government revenue shock, a government investment shock, a government (non-wage) consumption shock, a government wage shock, and a government employment shock. All fiscal shocks are identified by requiring that (i) they are orthogonal to the business cycle, the monetary policy and the rest fiscal shocks, and (ii) the respective fiscal instrument increases for quarters $k = 0, 1, 2, 3$ after the shock.[7]

For imposing both zero and sign restrictions we apply the methodology of Arias et al. (2014). This is the most appropriate for our aim for two reasons; firstly, it offers a faster procedure of identifying shocks using both zero and sign restrictions comparably to other methodologies; secondly, other sign restriction methodologies implicitly rely on conditionally agnostic priors (not trully agnostic priors), something avoided by the present approach (for detailed discussion see Arias et al. (2014)).

The sign restrictions are summarized in Table 1, while the identification algorithm is detailed

[6] In a subsequent study (Arias et al. (2016)) the authors discuss the risk of using both sign and zero restrictions to get conditionally agnostic priors. To check whether our analysis draws safe results we have also estimated impulse responses based on an identification of the monetary policy shock without zero restrictions (Uhlig (2005)). The results of this robustness exercise are qualitatively similar and available upon request.

[7] We have experimented with different number of restricted horizons from 1 to 4 periods. Since the implications of the analysis are similar and in order to follow the existing literature (Mountford and Uhlig (2009)), we use an horizon of four quarters as benchmark. Sensitivity analysis results are available upon request.

in Appendix C. The estimation of the VAR and the identification of shocks are based on N=500 draws from the posterior distribution of the VAR parameters and M=3000 draws of orthonormal matrices.

2.4 Results

2.4.1 The identified shocks to the government wage bill

Following the strategy outlined in the previous section, we identify shock series for government wages and employment at the federal and the S&L level. Figure 3 displays the median and the 68% confidence bands of the two structural shocks calculated from the VAR residuals at the different government levels. The values in the vertical axes correspond to standard deviations. It can be easily seen that the volatility of the shocks at the different government level is of similar magnitude. Notice that the peaks of the series at each government level do not coincide. For example, we observe a surge in federal government employment in 1990 and 2000, while S&L public employment is, if anything, increasing slightly in the 1990s and falls significantly in 2000. The fall in government employment around 1983 reflects cuts in the Reagan presidency era. The 1982 fiscal budget that was proposed by Reagan represented indeed a reduction of $44 billion, or 5.7%, and all categories of public employment, except national defense, were reduced. Over half of the $44 billion budget reduction came from two areas: income security; and education, training employment and social services that seemed to have affected more severely the S&L governments.

Big wage cuts occur in 1985, 1990 and 2001 at the S&L level, while in 1996 at the federal level. It seems that the cuts in public wages at the S&L level could be associated with the need of local governors to adjust the budget. For example, Governor Wilson of California pressed 21 government employee unions in 1991 to accept a 5% pay cut because the state was especially hard hit by the 1990-91 recession.[8] As long as this reaction does not constitute a systematic response to recessions, we conclude that confronting the identified shock series and real events, our identification strategy is successful in extracting meaningful public employment and wage shocks.

Additionally, we calculate the forecast error variance decomposition of private output and the public wage bill at the different government levels. The two public wage bill shocks at any government level explain together approximately 20-23% of private output at business cycle

[8] See Bureau of National Affairs (1991).

frequencies. On the other hand, the public wage bill shocks at the S&L level explain around 24% of public wage bill fluctuations, while the federal wage bill shocks explain 29% of public wage bill fluctuations. Moreover, public wage and employment shocks share equal roles in inducing business cycle fluctuations at any government level.[9]

2.4.2 Impulse response functions and multipliers

In Figure 4 we present the responses of output and its components, employment and the real wage in the private sector, as well as the unemployment and labor force participation rates, and also responses of tax revenues and the other spending components to the two fiscal shocks under investigation for the two government levels considered. For comparability purposes, employment and wage shocks are scaled to represent a 1% of GDP increase in the government wage bill.[10] Each graph presents median estimates (solid line) and pointwise 68% credible bands (dashed lines).

According to Figure 4, the shock to government employment significantly increases private output at both the federal and the S&L level. The timing of responses seems different: output increases significantly in the short run for shocks to government employment at the federal level and with a lag at the S&L level. Also, private consumption increases significantly after an increase of government employment at the S&L level, while it does not move after the same shock at the federal level. Similarly, private investment does not react significantly in the short run after a sudden increase in federal employment, while it falls and then increases with a considerable lag after an increase in S&L government employment. Private employment responses track both quantitatively and qualitatively the responses of private output, while private wages increase in a more pronounced way to shocks to S&L government employment. As before, the combined increase in private employment and the labor force participation renders the responses of unemployment insignificant. On the other hand, all fiscal variables seem to react insignificantly to the public employment shock at the federal level, but they may react with one or more lags at the S&L level.[11] Above all, government employment shocks have

[9] In the online Appendix, we present graphs for the forecast error variance decomposition of private output and the public wage bill. Our estimates are in line with the ones reported in the existing literature.

[10] As in Perotti (2014), the responses to government employment (wage) shocks are divided by the initial response of government employment (wage), and further divided by the sample mean ratio of the government wage bill to GDP. In other words, this scaling refers to an increase in the wage bill induced only by the shocked wage bill component, as if the other component was kept fixed.

[11] The fact that we have orthogonalized the shocks does not mean that the respective shocked fiscal instruments cannot react to each other contemporaneously or with a lag. In the next subsection, we investigate the sensitivity of our results in other VAR specifications that result to insignificant reactions of the rest fiscal variables to the

expansionary effects at the S&L level and, if any, only mildly expansionary impact at the federal level.

Shocks to the public wage at the federal level induce a significant drop in private output, employment and (almost) investment, and a significant surge in unemployment, while shocks to the S&L government wages induce significant increases in private output, consumption and investment, a significant and persistent increase in private wages and no significant effects on private employment, unemployment and labor force participation. These differential economic effects are also reflected in the responses of tax revenues, which fall significantly after shocks to federal public wages but increase significantly after shocks to S&L government wages. The rest of the fiscal variables are not affected significantly by the public wage shock at the federal level. At the S&L level, government wage increases induce significant and persistent increases in government investment and tax revenues.

The difference in the impulse responses translates into differences in the fiscal multipliers. Table 2 presents point estimates of the impact output multipliers and the present-value cumulative multipliers up to five years after the shock. Multipliers are computed according to Mountford and Uhlig (2009). The exact formula is presented in Appendix C. In parenthesis we report 68% credible sets for the computed multipliers. A 1% of GDP increase in the government wage bill induced by a shock to federal government employment implies a significant expansion of private output by 0.59% and 0.92% on impact and one year after the shock, respectively. On the contrary, a 1% of GDP increase in the government wage bill induced by a shock to federal government wages implies a contraction in private production by -1.22% and -0.59% one and two years after the shock, respectively. Finally, at the S&L level, multipliers are positive and significant for both shocks on impact and at later horizons. As noted earlier, multipliers at the S&L level for government employment shocks are significantly higher than at the federal level.

In the online Appendix, we include the impulse responses following shocks to 'total' government employment, defined as the sum of federal and S&L government employment, and to the 'total' government wage, defined as the average of the federal and S&L government wage rates. Given the important differences observed at the two different government levels, it does not come as a surprise that adding the two results in mostly non-significant effects. At the aggregate level, government wage shocks imply insignificant output multipliers, while a 1% of GDP increase in the government wage bill induced by a shock to government employment raises output by 1.34% on impact.

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identified fiscal shock.

2.5 Robustness

2.5.1 Controlling for all government levels

When identifying shocks to the federal or S&L public wage component one may worry that such shocks are correlated. Increases in the wages of federal employees might correlate with increases in the wages of public employees at the S&L level, for instance. Our benchmark results confirm this for some of the VARs considered. To check the sensitivity of our results to the possible correlation of shocks to federal and local government wage bill spending, we repeat the estimation now controlling for the co-existence of federal and S&L shocks in the same VAR. In other words, when identifying federal (S&L) government shocks we further require the shocks to be orthogonal to a generic S&L (federal) government spending shock. We use the same VAR model enhancing it with an extra variable that stands for either the federal or S&L government expenditure. The extra shock to federal (S&L) government spending is identified by making it orthogonal to all the rest of shocks, and further requiring federal (S&L) government spending to increase for quarters $k = 0, 1, 2, 3$ after the shock. Figure 5 shows the impulse responses to federal and S&L government spending shocks, while the middle panel of Table 2 presents the respective output multipliers. As can be easily seen, results remain unchanged: government employment shocks remain robustly expansionary at both government levels, and have higher effects at the S&L level. S&L government wage increases also expand output and employment in the private sector, while federal wage increases have contractionary effects. Multipliers are also comparable.

2.5.2 An alternative identification scheme

Another robustness exercise is related to the identification scheme used to extract the fiscal shocks. In particular, we repeat our VAR analysis extracting the fiscal shocks using a simple recursive (Choleski) identification (Blanchard and Perotti (2002)). We keep the same ordering of the variables as it is stated in the benchmark VAR specification. Impulse responses to federal and S&L shocks are presented in Figure 6. As in our benchmark specification, a public employment increase leads to a significant expansion of private output, consumption and employment, and a significant increase in the participation rate. Those effects hold across any government level and are stronger at the S&L level, as before. Federal wage shocks induce contractionary effects on output and employment in the private sector, while S&L government wage shocks are clearly expansionary, thus further confirming our benchmark conclusions. As demonstrated in

Table 2 (bottom panel), the ranking and sign of the multipliers are similar to the ones obtained when we use sign restrictions to recover the shocks.[12]

3 Theoretical analysis

In this section we develop a New Keynesian model with a public sector, search and matching frictions, and endogenous labor force participation. We assume that a public good produced in the economy provides both productive services to private sector firms and utility-enhancing services to the representative household. There are three types of firms in the economy: (i) a public firm that produces the public good, which is provided for free (ii) private competitive intermediate firms that use private inputs and the public good to produce a final good; (iii) monopolistic competitive retailers that use all intermediate varieties to produce the final good. Price rigidities arise at the retail level, while search frictions occur in the intermediate goods sector. The household's members consist of employees, unemployed, and labor force non-participants. The government collects taxes and uses revenues to finance public expenditures, the cost of new vacancies in the public sector and the provision of unemployment benefits.

3.1 The model

3.1.1 Labor markets

In each period, jobs in each sector $j = p, g$ (i.e. private/public) are destroyed at a constant fraction σ^j and a measure m^j of new matches are formed. The evolution of employment in each sector is thus given by:

$$n_t^j = (1 - \sigma^j) n_{t-1}^j + m_t^j \tag{1}$$

where we assume that matches become productive in the same period. The government, upon forming a match, makes a take-it-or-leave-it offer to matched workers. We also assume that $\sigma^p > \sigma^g$ in order to capture the fact that, relatively speaking, the public sector is characterized by greater job security.[13] We consider search as being random and so there is one matching

[12]Results also hold when we change the ordering of the VAR, and they are available from the authors upon request.

[13]According to CBO estimates for the period 2005-2010, wages were on average higher for workers in the federal government than for private-sector workers (Falk (2012)).

function that has unemployment, u_t, and the total number of vacancies, υ_t^p and υ_t^g, as inputs:

$$m_t^p + m_t^g = \rho_m (\upsilon_t^p + \upsilon_t^g)^{\alpha} {u_t}^{1-\alpha} \tag{2}$$

where the matching efficiency is given by ρ_m. We also assume equal vacancy filling probabilities in the two sectors:

$$\frac{\upsilon_t^g}{\upsilon_t^p} = \frac{m_t^g}{m_t^p} \tag{3}$$

3.1.2 Households

The representative household consists of a continuum of infinitely lived agents. The members of the household derive utility from leisure, which corresponds to the fraction of members that are out of the labor force, l_t, and a consumption bundle, cc_t, defined as:

$$cc_t = [\alpha_1 (c_t)^{\alpha_2} + (1-\alpha_1)(y_t^g)^{\alpha_2}]^{\frac{1}{\alpha_2}}$$

where y_t^g denotes a public good, taken as exogenous by the household, and c_t is private consumption. The instantaneous utility function is given by:

$$U(cc_t, l_t) = \frac{cc_t^{1-\eta}}{1-\eta} + \Phi \frac{l_t^{1-\varphi}}{1-\varphi}$$

where η is the inverse of the intertemporal elasticity of substitution, $\Phi > 0$ is the relative preference for leisure, and φ is the inverse of the Frisch elasticity of labor supply. The elasticity of substitution between the private and public goods is given by $\frac{\eta}{1-\alpha_2}$.[14]

At any point in time, a fraction n_t^j of the household members are employed in sector $j = p, g$ (i.e. private/public). Following Ravn (2008), the labor force participation choice is modelled as a trade-off between the cost of giving up leisure and the prospect of finding a job. In particular, the household chooses the fraction of the unemployed actively searching for a job, u_t, and the fraction which are out of the labor force and enjoying leisure, l_t, so that:

$$n_t + u_t + l_t = 1 \tag{4}$$

[14]When this elasticity is greater than one, c_t and y_t^g are substitutes, while when it is below one, they are complements. The Cobb-Douglas specification is obtained when the elasticity is equal to zero.

where $n_t = n_t^p + n_t^g$. The household owns the private capital stock, which evolves over time according to:

$$k_{t+1}^p = i_t^p + (1-\delta^p)k_t^p - \frac{\omega}{2}\left(\frac{k_{t+1}^p}{k_t^p} - 1\right)^2 k_t^p \tag{5}$$

where i_t^p is private investment, δ^p is a constant depreciation rate and $\frac{\omega}{2}\left(\frac{k_{t+1}^p}{k_t^p} - 1\right)^2 k_t^p$ are adjustment costs. The intertemporal budget constraint is given by:

$$c_t + i_t^p + \frac{B_{t+1}\pi_{t+1}}{R_t} \leq [r_t^p - \tau_k(r_t^p - \delta^p)]k_t^p + (1-\tau_n)(w_t^p n_t^p + w_t^g n_t^g) + \varpi u_t + B_t + \Pi_t^p + T_t \tag{6}$$

where $\pi_t \equiv p_t/p_{t-1}$ is the gross inflation rate, w_t^j, $j = p, g$, is the real wage in each sector, r_t^p is the real return on capital, ϖ denotes unemployment benefits, B_t is the real government bond holdings, R_t is the gross nominal interest rate, Π_t^p are the profits of the monopolistic retailers, discussed below, and τ_k, τ_n, T_t represent taxes on private capital, labor income and lump-sum transfers, respectively. The household's first order conditions and the expected marginal value to the household of having an additional member employed in the private sector are reported in Appendix D.

3.1.3 Production

Intermediate goods firms Intermediate goods are produced with a Cobb-Douglas technology:

$$y_t^p = (\varepsilon_t^A n_t^p)^{1-\psi}(k_t^p)^{\psi}(y_t^g)^{\nu} \tag{7}$$

where ε_t^A is an aggregate technology shock, k_t^p and n_t^p are private capital and labor inputs, and y_t^g is the public good used in production, taken as exogenous by the firms. The public good is provided for free. The parameter ν regulates how the public input affects private production: when ν is zero, the government good is unproductive.

Since current hires give future value to intermediate firms, the optimization problem is dynamic and hence firms maximize the discounted value of future profits. The number of workers currently employed, n_t^p, is taken as given and the employment decision concerns the number of vacancies posted in the current period, v_t^p, so as to employ the desired number of workers, n_t^p. Firms also decide the amount of the private capital, k_t^p, needed for production.

The problem of an intermediate firm consists of choosing k_t^p and υ_t^p to maximize:

$$Q^p(n_t^p, k_t^p) = \max_{k_t^p, \upsilon_t^p} \left\{ x_t y_t^p - w_t^p n_t^p - r_t^p k_t^p - \kappa \upsilon_t^p + E_t \left[\Lambda_{t,t+1} Q^p(n_{t+1}^p, k_{t+1}^p) \right] \right\} \tag{8}$$

where x_t is the relative price of intermediate goods, κ is a utility cost associated with posting a new vacancy, and $\Lambda_{t,t+1} = \frac{\beta^s U_{c_{t+s}}}{U_{c_t}}$ is a discount factor. The maximization takes place subject to the private employment transition equation:

$$n_t^p = (1 - \sigma^p) n_{t-1}^p + \psi_t^{fp} \upsilon_t^p \tag{9}$$

The first-order conditions are:

$$x_t \psi \frac{y_t^p}{k_t^p} = r_t^p \tag{10}$$

$$\frac{\kappa}{\psi_t^{fp}} = x_t (1 - \psi) \frac{y_t^p}{n_t^p} - w_t^p + E_t \Lambda_{t,t+1} [(1 - \sigma^p) \frac{\varkappa}{\psi_{t+1}^{fp}}] \tag{11}$$

According to (10) and (11) the value of the marginal product of private capital should equal the real rental rate and the marginal cost of opening a vacancy should equal the expected marginal benefit. The latter includes the marginal productivity of labor minus the wage plus the continuation value, knowing that with probability σ^p the match can be destroyed.

The expected value of the marginal job for the intermediate firm, $V_{n^p t}^F$ is:

$$V_{n^p t}^F \equiv \frac{\partial Q^p}{\partial n_t^p} = x_t (1 - \psi) \frac{y_t^p}{n_t^p} - w_t^p + \frac{(1 - \sigma^p) \kappa}{\psi_t^{fp}} \tag{12}$$

Retailers There is a continuum of monopolistically competitive retailers indexed by i on the unit interval. Retailers buy intermediate goods and differentiate them with a technology that transforms one unit of intermediate goods into one unit of retail goods, and thus the relative price of intermediate goods, xt, coincides with the real marginal cost faced by the retailers. Let y_{it} be the quantity of output sold by retailer i. The final consumption good can be expressed as:

$$y_t = \left[\int_0^1 (y_{it})^{\frac{\epsilon - 1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon - 1}}$$

where $\epsilon > 1$ is the constant elasticity of demand for retail goods. The final good is sold at a price $p_t = \left[\int_0^1 p_{it}^{1-\epsilon} di\right]^{\frac{1}{1-\epsilon}}$. The demand for each intermediate good depends on its relative price and on aggregate demand:

$$y_{it} = \left(\frac{p_{it}}{p_t}\right)^{-\epsilon} y_t$$

Following Calvo (1983), we assume that in any given period each retailer can reset its price with a fixed probability $(1 - \chi)$. Hence, the price index is given by:

$$p_t = \left[(1-\chi)(p_t^*)^{1-\epsilon} + \chi(p_{t-1})^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}} \tag{13}$$

Firms that are able to reset their price choose p_{it}^* so as to maximize expected profits given by:

$$E_t \sum_{s=0}^{\infty} \chi^s \Lambda_{t,t+s}(p_{it}^* - p_{t+s}^x) y_{it+s}$$

The resulting expression for p_{it}^* is:

$$p_{it}^* = \frac{\epsilon}{\epsilon - 1} \frac{E_t \sum_{s=0}^{\infty} \chi^s \Lambda_{t,t+s} p_{t+s}^x y_{it+s}}{E_t \sum_{s=0}^{\infty} \chi^s \Lambda_{t,t+s} y_{it+s}} \tag{14}$$

3.1.4 Wage bargaining

Wages are determined by ex post (after matching) Nash bargaining. Workers and firms split rents and the part of the surplus they receive depends on their bargaining power. If we denote by $\vartheta \in (0, 1)$ the firms' bargaining power, the Nash bargaining problem is to maximize the weighted sum of log surpluses:

$$\max_{w_t^p} \left\{(1-\vartheta) \ln V_{n^p t}^H + \vartheta \ln V_{n^p t}^F\right\}$$

where $V_{n^p t}^H$ and $V_{n^p t}^F$ have been defined above. The optimization problem leads to the following solution for w_t^p:

$$w_t^p = (1-\vartheta)[x_t(1-\psi)\frac{y_t^p}{n_t^p} + \frac{(1-\sigma^p)\kappa}{\psi_t^{fp}} \psi_t^{hp}] + \frac{\vartheta}{(1-\tau_n)\lambda_{c,t}}(\Phi l_t^{-\varphi} - (1-\sigma^p)\lambda_{n,t}) \tag{15}$$

Hence, the equilibrium wage is the sum of the value of the marginal product of employment and the value to the firm of the marginal job multiplied by the hiring probability, weighted by the worker's bargaining power, and the outside option of being unemployed, weighted by the firm's bargaining power.

3.1.5 Government

The government sector produces the public good using public capital and labor:

$$y_t^g = (\varepsilon_t^A n_t^g)^{1-\mu}(k_t^g)^{\mu} \tag{16}$$

where we assume that TFP shocks, ε_t^A, are not sector specific and μ is the share of public capital. The government holds the public capital stock. Similar to the case of private capital, the government capital stock evolves according to:

$$k_{t+1}^g = i_t^g + (1-\delta^g)k_t^g - \frac{\omega}{2}\left(\frac{k_{t+1}^g}{k_t^g} - 1\right)^2 k_t^g \tag{17}$$

Government expenditure consists of government consumption, modelled as a waste, public investment, public wage payments, public vacancy costs, unemployment benefits, and lump-sum transfers, while revenues come from the capital and labor income. The government deficit is therefore defined by:

$$DF_t = c_t^g + i_t^g + w_t^g n_t^g + \kappa v_t^g + \varpi u_t - TR_t$$

where $TR_t \equiv (w_t^p n_t^p + w_t^g n_t^g) + \tau_k(r_t^p - \delta^p)k_t^p - T_t$ denotes tax revenues net of transfers. The government budget constraint is given by:

$$B_t + DF_t = R_t^{-1} B_{t+1} \pi_{t+1}$$

To ensure determinacy of equilibrium and a non-explosive solution for debt (see e.g. Leeper (1991)), we assume a debt-targeting rule of the form:

$$T_t = \overline{T}\exp(\zeta_{ß}(ß_t - \overline{ß})) \tag{18}$$

where $\overline{ß}$ is the steady state level of debt to GDP ratio, $ß_t = \frac{B_t}{y_t}$. If $\Psi^g = \upsilon^g$, w^g, c^g denotes the different fiscal instruments, we assume fiscal rules of the form:

$$\Psi_t^g = \overline{\Psi}^g \left(\Psi_{t-1}^g\right)^{\varrho_g^\psi} \exp(\varepsilon_t^{\psi^g}) \tag{19}$$

where $\varepsilon_t^{\psi^g}$ is a zero-mean, white-noise disturbance, and ρ_g^ψ determines the persistence of the different processes.

3.1.6 Monetary policy

There is an independent monetary authority that sets the nominal interest rate as a function of current inflation according to the rule:

$$R_t = \bar{R}\left(R_{t-1}\right)^{\varrho_R} \exp(\zeta_\pi \pi_t + \varepsilon_t^R) \tag{20}$$

where ε_t^R is a monetary policy shock and π_t measures inflation in deviation from the steady state.

3.1.7 Resource constraint

Private output must equal private and public demand. The resource constraint is given by:

$$y_t^p = c_t^p + i_t^p + c_t^g + i_t^g + \kappa(\upsilon_t^p + \upsilon_t^g) \tag{21}$$

3.2 Calibration

We solve the model by linearizing the equilibrium conditions around a non-stochastic steady state in which all prices are flexible, the price of the private good is normalized to unity, and inflation is zero. We calibrate the model for the U.S. at a quarterly frequency. Table 3 shows the key parameters and steady-state values targeted in our calibration.

We calibrate the labor force participation and unemployment rate to match the observed average values. Thus, we set labor force participation, 1-$l \equiv n + u$, equal to 65% and the unemployment rate to 6.5%. We fix the separation rate in the public sector $\sigma^g = 0.045$ and in the private sector $\sigma^p = 0.05$, which is comparable with the estimates for the job separation rate in Hobijn and Sahin (2009). We fix the probability of filling a vacancy and then we use it to derived steady-state vacancies in each sector ($v^j = m^j/\psi^{fj}$). We use the value $\psi^{fp} = 0.4$, which allows us to obtain meaningful values for vacancies ($v^p = 0.064$, $v^g = 0.011$). For the matching elasticity with respect to vacancies we use $a = 0.6$. Hiring probabilities for each sector are computed as the ratio of sector-specific matches to unemployed jobseekers.

The capital depreciation rates, δ^g and δ^p, are set equal to 0.025. Following the literature, we set the discount factor $\beta = 0.99$, which implies a quarterly real rate of interest of approximately 1%. The elasticity of demand for retail goods, ϵ, is set such that the gross steady state markup, $\frac{\epsilon}{\epsilon-1}$, is equal to 1.25, and the price of the final good is normalized to one. The TFP parameter, A, is normalized to one. For the capital share in the private sector production function we assume a standard value $\psi = 0.36$, and in the public sector production function we use $\mu = 0.1$. We set the capital ratio $k^g/k^p = 0.31$ using data from Kamps (2006).

We set the replacement rate $\frac{\varpi}{w^p} = 0.45$, following Brückner and Pappa (2012). Steady-state tax rates are calibrated to the values in Traum and Yang (2015), which are mean values from U.S. data over the period 1983-2008. The ratio of public consumption to output is set equal to 6%, according to the mean value in our data. The steady state debt-to-GDP ratio takes the value $ß_t = 60\%$ annually. In absence of a consensus on the magnitude of this coefficient in the literature, with estimates ranging from 0.39 to 0.56 in Aschauer (1989) for the elasticity of output with respect to public capital to lower values in Garcia-Mila and McGuire (1992) or even zero in Holtz-Eakin (1994), we set $\nu = 0.15$ and perform sensitivity analysis on this parameter in Section 3.5, where we show that our results do not depend on the choice of this parameter. We set $\alpha_1 = 0.95$ for the share of private consumption in the aggregate consumption bundle of the household. Regarding the inverse elasticity of intertemporal substitution, η, much of the literature cites the econometric estimates of Hansen and Singleton (1983), which place it "between 0 and 2". In our calibration, we set $\eta = 0.5$. Following the literature on Edgeworth complementarity between private and public consumption goods (see, e.g., Bouakez and Rebei (2007), Fiorito and Kollintzas (2004), Fève et al. (2013)), we set $\alpha_2 = -1.95$, which implies elasticity of substitution between the private and public goods given by $\frac{\eta}{1-\alpha_2}$ equal to -0.5. The inverse of the Frisch elasticity, φ, is set equal to 1.5, in the range of Domeij and Floden (2006).

Finally, the model's steady state is independent of the degree of price rigidities, the monetary policy rule, and the size of the capital adjustment costs. Capital adjustment costs are included to moderate the response of investment with respect to fiscal shocks. We set the inflation targeting parameter in the Taylor rule $\zeta_\pi = 1.5$, the capital adjustment costs parameter $\omega = 1$, and the price-stickiness parameter $\chi = 0.75$.

3.3 Results

In Figure 7 we present impulse response functions to a 1% of steady state output increase in the public wage bill induced by an increase in public vacancies (top panel) and in public wages (bottom panel).[15] All responses are expressed in percentage deviations from respective steady state values, with the exception of the unemployment and labor force participation rates that are expressed in absolute percentage points. We first report the results of our benchmark parameterization (solid lines) for which public wage shocks have contractionary effects on private sector production in the short run. We then investigate which are the key elements of the model that can account for the case of positive output effects, as found for S&L government wage shocks.

The predictions of our theoretical model match well the empirical evidence for public employment shocks (see Figure 7 (top panel)). It can be readily seen that this type of shocks to the government wage bill is expansionary for the private sector by crowding in consumption and increasing labor force participation and employment. In particular, the complementarity of the public good with private consumption in the aggregate consumption bundle of the household overturns the negative wealth effect of the shock and leads to an increase in private consumption (after the impact period). The unemployment rate rises due to the increase in labor market participation.

Our model can also explain how government wage shocks can be contractionary or expansionary, as found in the data, depending on the relative magnitude of the forces at play. More specifically, wage shocks lead to public-private wage spillovers, inducing a negative labor demand effect, which is reflected in the response of private vacancies, and a fall in employment in the private sector, as well as an increase in unemployment. At the same time, there is a boost in the production of the public good as labor supply and employment in the public sector increase. Consequently, public wage shocks can lead to a crowd in of private consumption given the complementarity of the latter with the public good in the aggregate consumption bundle of the household. These two opposite channels can help explain the empirical results. As we can see in Figure 7 (bottom panel), with our benchmark calibration, we observe a short run contraction in private-sector production and a rise in the unemployment rate, which matches the empirical evidence found for federal government wage shocks. In this case, the complementarity channel is not sufficiently strong to overturn the wage increase and the negative labor demand

[15] In the Online Appendix, we present responses for the other three shocks in the model, namely a government consumption, a monetary policy, and a business cycle shock. The model does well in matching qualitatively the responses in the empirical model.

effect in the private sector. We next examine whether increasing the degree of complementarity between the public good and private consumption can generate an expansion in the private sector, as observed in the data for S&L government wage shocks.

3.4 The complementarity between public and private goods

As already emphasized, the degree of complementarity between the public good and private consumption in the aggregate consumption bundle of the household is key for determining the effects of government wage bill shocks. In this subsection, we investigate how varying the degree of this complementarity affects the transmission of both types of shocks to the public wage bill. The dashed lines in Figure 7 (top panel) represent responses to a shock in government vacancies when we increase the degree of complementarity between public and private goods (by setting $\alpha_2 = -3.9$). As we can see, the effects of government vacancy shocks are significantly more pronounced than in our benchmark calibration. This is line with the empirical evidence for public employment shocks exhibiting stronger effects at the S&L level relative to the federal level. Turning to the public wage shocks (see Figure 7, bottom panel), with a higher complementarity between public and private goods, the increase in private consumption becomes larger, and the fall in private employment becomes smaller and short-lived, and so does the rise in the private wage. The increase in public employment and output leads now to an expansion in private-sector production.

Our theoretical analysis therefore suggests that the degree of complementarity with private consumption at the S&L and federal level is key for explaining the observed heterogeneity to wage bill shocks.[16] The differential macroeconomic effects of public wage shocks can be justified by the different nature of the public good provided in each government level. For instance, federal government employees largely comprise military employees, and even one-third of the federal civilian workforce are employed in the Department of Defense.[17] On the other hand, S&L government employees provide mainly education, health care and transportation services.[18]

[16] As pointed out by a referee, preferences with complementarity of hours and consumption would in principle allow us to fit the increase in private activity after an increase in government employment, but this would go against the federal and S&L distinction.

[17] Falk (2012) provides detailed information on the occupational tasks of the federal civilian workforce: 57% of this workforce worked at three departments in 2010: (i) the Department of Defense employs more than one-third; (ii) the Department of Veterans Affairs employs 14%; (iii) the Department of Homeland Security employs 8%. Another 40% of federal civilian employees work for the other departments and agencies of the executive branch, while the remaining 3% is employed by the legislative and judicial branches of government.

[18] As reported by McNichol (2012), by far the largest share of S&L government workers in 2010 were the nearly 7 million teachers and support staff working in the nation's schools. Other important categories of S&L

Research by Fiorito and Kollintzas (2004) with European data has indeed shown that the degree of complementarity between government and private consumptions is not homogeneous over types of public expenditures. In particular, they find that while some categories of public spending seem to be substitutable with private consumption, there are also public expenditure categories which are complements to private spending. More importantly, they report that the latter case of complementarity seems to be the stronger relation, such that overall government and private consumption are complements in the aggregate. 'Merit goods', including health and education, complement private consumption while 'public goods', referring to defense, public order and justice, are substitutes with private consumption. Bouakez and Rebei (2007) further note that examples of public goods that are highly complementary with private consumption include education and transportation. This idea is in line with recent work by Perotti (2014) who shows that defense spending shocks in a SVAR generate 'contractionary' responses, while civilian government spending shocks generate large 'expansionary' responses. The theoretical explanation provided in that paper is based on the assumption that civilian spending exhibits Edgeworth complementarity with private consumption, while defense spending is a waste. In a similar vein, Pieroni and Lorusso (2015) present VAR estimates for the U.S. economy showing that government civilian expenditure induces a positive response on private consumption, whereas military spending has a negative impact.

3.5 Sensitivity analysis: The importance of complementarity against other possible hypotheses

The previous subsection has highlighted that the model can explain the heterogeneity of responses of the empirical model at the different government levels if one accepts the idea that public goods at the S&L level are 'merit' goods, while the goods produced at the federal level are 'public' goods, according to the terminology adopted in Fiorito and Kollintzas (2004). Yet, there are many characteristics in the model that could potentially explain the differences in results at the different government levels. For example, one might ask whether the presence of the public good in the production function of the private sector could be an alternative channel that can explain the mixed sign of the output response for public wage shocks. Also, vacancy filling probabilities in the public sector at the S&L level might differ from those at the federal

employment are protective services (including police officers and fire fighters), higher education, health care, and transportation (including road maintenance workers and bus drivers).

level, or simply the level of income taxes might differ at the two government levels and this could explain the differences in responses.

In order to control for all those possible hypotheses and to validate the prediction of our DSGE model concerning the role of complementarity between public output and private consumption in explaining the heterogeneity of empirical responses, in this section following Leeper et al. (2015) we resort to a sort of prior predictive analysis. What we are looking for here is to establish that the degree of complementarity between private consumption and public good is the key for explaining the differences in S&L and federal responses even when we allow for variations in other parameters of the model that could also be important in explaining the differences. Our prior predictive analysis produces the entire range of the model's possible impulse responses when we change parameters that could differ at the S&L and federal level and can shed light on our model's predictions to confront with the data.

Formally speaking, let $h(y_t(\theta|x_t)))$ be a $J \times 1$ vector of functions of the data y_t produced by the model, when the $N \times 1$ vector of structural parameters θ is employed, conditional on the shock x_t. We let θ be uniformly distributed over Θ , where $\Theta = \prod_i \Theta_i$ is the set of admissible parameter values and Θ_i is an interval for each parameter i. We draw $\theta_i^l, i = 1, \ldots, N$ from each Θ_i, construct $h(y_t(\theta^l|x_t)))$ for each draw $l = 1, \ldots, 10000$ and order them increasingly. Then we report the 84 and 16 percentiles of the simulated distribution of $h(y_t(\theta|x_t)))$, where $h(.)$ stands for the model's impulse responses when we vary the related parameters. Since the 68% bands of the IRFs track well the responses in the empirical model and are significantly different when we change only the complementarity degree of the public good with private consumption in the utility specification, we conclude that the value of the degree of complementarity is key for explaining the empirical results.

We restrict the range of Θ_i on the basis of theoretical and practical considerations and draw uniformly from these ranges. This way our approach also formalizes, via Monte Carlo methods, standard sensitivity analysis conducted in many calibration exercises. We split the parameter vector $\theta = (\theta_1, \theta_2)$, where θ_1 represents the parameters which are fixed to a particular value, either to avoid indeterminacies or because of steady state considerations, while θ_2 are the parameters which are allowed to vary between the two government levels. Table 3 gives the ranges for the parameters in θ_2.

The vector θ_1 includes the discount factor, the steady state TFP level, the debt to GDP ratio and the risk aversion parameter. The intervals for the parameters that vary in our robustness exercise are centered around the benchmark calibrated values. For example, we allow the vacancy filling probabilities in the private and public sector to vary in the [0.3,0.5] interval. The share of public employees in total employment is much smaller in the federal level than in the benchmark calibration. For that reason when constructing our priors we allow this papemeter to vary in the [0.5,0.18] interval. We assume also differences in the unemployment rate, the replacement rates, the job destruction probabilities of jobs at the S&L and federal level and differences in the matching efficiencies varying this parameter at the [0.45,0.65] interval. The labor supply elasticity, which is crucial in determining the labor market responses to fiscal shocks and may differ for federal versus S&L jobs, varies in the interval [0.25,1], which covers well the range of existing estimates. The capital adjustment costs parameter shapes investment responses to shocks and therefore indirectly affects labor market dynamics. The chosen range allows for small (ϖ=0.1) and large (ϖ=3) adjustment costs. We also vary private and public capital depreciation rates. The parameter ν controls the interactions between public and private goods in production. Depending on its value, an increase in government capital has large, or small effects on private output. Aschauer (1989) estimates the elasticity of output with respect to public capital in a range from 0.39 to 0.56. Evidence from more recent studies, however, suggests positive, but lower, values for ν both at national and at the regional level (see, e.g., Garcia-Mila and McGuire (1992)). In our model we use public output rather than public capital in the private production function, we choose for ν the range [0, 0.2], which covers both the case of unproductive government output and most of the estimates for the elasticity of output to changes in public capital in the literature. We vary the productivity of public capital at the [0,0.3] range and the public to private capital ratio between [0.25,0.35].

The degree of price stickiness and the coefficient on inflation in the policy rule determine both the shape and the size of output and inflation responses following a fiscal shock. Since at the state level nominal price rigidities might be less severe than at the federal level and their interaction with monetary policy might operate differently, we post intervals both for the degree of price stickiness as well as the inflation coefficient in the Taylor rule. Notice that the determinacy of equilibrium depends nonlinearly on the values of χ, ζ_π and ζ_b, for that reason the ranges of these parameters are truncated so as to guarantee determinacy. Finally, the persistence of the government wage bill shocks is allowed to vary between [0,1,0.9].

We report the 68% confidence of the model IRFs in Figure 8 when we consider high and low values for the parameter α_2 that determines the degree of complementarity between public goods and private consumption. For low complementarity we assume the interval [-2,-0.5] that implies CES elasticities between private and public goods in the range [0.16,0.33], while for high complementarity values we use the interval [-3,-5] which implies CES elasticities in the range [0.08,0.13]. The graphs clearly indicate that even if we vary the parameters of the rest of the model that could also be responsible for the differential macroeconomic responses at the S&L and federal level, still the complementarity between public output and private consumption is key for explaining the pattern of empirical responses. Our analysis suggests that a model that permits government output to complement private consumption for different levels of unemployment or taxes at the S&L and federal level and persistence of fiscal shock and for various values of the labor supply elasticity or productivity of public capital is capable of explaining the positive output responses after a government wage shock and the high multipliers of a government employment shock at the S&L level.

In Figure 8 output, employment and consumption responses to vacancy shocks when we consider the range of strong complementarity are on average larger than in the case we consider the low complementarity interval. On the other hand, the 68% confidence bands for the responses of output in Figure 8 are above zero when we consider strong complementarity and below when the degree of complementarity we assume is low. A similar picture emerges for the responses of private employment. The probability that output responses are positive after a government employment shock for the range of low CES elasticity equals 0.93 and for high CES elasticity this probability equals 0.97. For government wage shocks the probability of obtaining positive output responses when the degree of complementarity assumes values in the low interval is 0.04, while for the high complementarity interval the probability of obtaining positive output multipliers is 0.88. Hence, the analysis of this section clearly indicates that the degree of complementarity between private and public goods is key for explaining the observed heterogeneity at the different government levels.

4 Concluding remarks

This paper estimated the macroeconomic effects of public wage expenditures in the U.S. by identifying shocks to public employment and public wages. The effects of public wage shocks are contractionary at the federal level and expansionary at the S&L level. On the other hand, public employment shocks are expansionary at both government levels by crowding in private consumption and increasing labor force participation and private-sector employment. Shocks to S&L government wages lead to a similar crowd in of private consumption, while shocks to federal government wages lead to public-private wage spillovers, inducing a negative labor demand effect, a sharp fall in private-sector employment and an increase in unemployment. We developed a stylized DSGE model with a public good providing both productive and utility-enhancing services, search and matching frictions, and endogenous labor force participation, which was able to explain the qualitative properties of the empirical evidence. The unique feature that can explain theoretically the heterogeneity of macroeconomic responses to government wage and employment shocks at the S&L and federal level is the complementarity of private and public goods. Empirical responses are compatible with the theoretical ones if one is willing to accept that the public goods produced at the S&L level are stronger complements with private goods relative to public goods produced at the federal level.

Our analysis therefore suggests that the public good provided at the federal level may exhibit a different degree of complementarity with private consumption than that at S&L level. This might be justified by the different nature of the public good provided in each case. For instance, federal government employees largely comprise military and defense employees, while S&L government employees provide mainly education, health care and transportation services. Our work has a number of useful policy implications in the aftermath of the crisis and the slow recovery in advanced countries. In particular, increases in public employment can stimulate the private sector's employment, encourage labor force participation and private demand. On the other hand, public wage policies could be expansionary only if the increases in wages are associated with the production of those public goods that strongly complement private consumption. Wage increases should target, for instance, employees that work in public education or the public health system.

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APPENDIX

A Data definitions and sources

G*overnment consumption*: Consumption expenditures, Item 21, Table 3.2. (Federal Government) - Item 23, Table 3.3. (S&L Governments) - Government Current Receipts and Expenditures, Source: Bureau of Economic Analysis.

G*overnment wage bill:* Compensation of general government employees, Item 15 (Federal Government) - Item 50 (S&L Governments), Table 3.10.5. Government Consumption Expenditures and General Government Gross Output, Source: Bureau of Economic Analysis.

G*overnment non-wage consumption*: G*overnment consumption* minus G*overnment wage bill*

Government investment: Item 41, Table 3.2. (Federal Government) - Item 39, Table 3.3. (S&L Governments) - Government Current Receipts and Expenditures, Source: Bureau of Economic Analysis.

Civilian government employment (Federal): All Employees: Government: Federal, CES9091000001, Source: US. Bureau of Labor Statistics.

Government employment (State and Local): *Civilian government employment (Total)* minus *Civilian government employment (Federal)*

Government employment (Federal): the sum of *Civilian government employment (Federal)* and *Military employment*

Military employment: Source: Ramey's (2011) dataset

Government hourly wage rate: Series have been constructed using the NBER extracts of the CPS Merged Outgoing Rotation Groups to generate the following: national-level, quarterly data for two wage categories: (a) federal government, (b) S&L governments (excluding from the sample workers that have never been full time and self-employed). Hourly wages were obtained for all workers using weekly wages and dividing by hours worked. We regressed for the repeated (monthly) cross section the log of hourly wage – separately for each of the two categories – on socio-demographic variables (age group, gender, race, and marital status). We also included dummies for each state. We ran the regression at the monthly level and then calculated residuals for each month. We averaged residuals by month and used the mid-quarter month to obtain quarterly data. We seasonally adjusted the quarterly data using a seasonal ARIMA model and deflated using the U.S. CPI quarterly inflation series.

Net (of transfers) tax revenue (Federal): Current tax receipts (Item 2) plus Contributions for government social insurance (Item 11) plus Current transfer receipts (Item 16) minus Current transfer payments (Item 22) minus Subsidies (Item 32), Table 3.2. Government Current Receipts and Expenditures, Source: Bureau of Economic Analysis.

Net (of transfers) tax revenue (State and Local): Current tax receipts (Item 2) plus Contributions for government social insurance (Item 11) plus Current transfer receipts (Item 16) minus Current transfer payments (Item 24) minus Subsidies (Item 30), Table 3.3. Government Current Receipts and Expenditures, Source: Bureau of Economic Analysis.

Total output: Gross domestic product, Item 1, Table 1.1.5. Gross Domestic Product, Source: Bureau of Economic Analysis.

Private output: *Total output* minus *Government wage bill.*

Private consumption: Personal consumption expenditures of non-durables and services, Items 5+6, Table 1.1.5. Gross Domestic Product, Source: Bureau of Economic Analysis.

Private investment: Non-residential investment, Item 9, Table 1.1.5. Gross Domestic Product, Source: Bureau of Economic Analysis.

Private employment: All Employees: Private, CES0500000001, Source: U.S. Bureau of Labor Statistics.

Private hourly wage rate: Series have been constructed using the NBER extracts of the CPS Merged Outgoing Rotation Groups in the same manner as the series for public wages. We use also alternative series for the private wage rate defined as Nonfarm Business Sector: Real Compensation Per Hour, Source: U.S.. Bureau of Labor Statistics.

Unemployment rate: Unemployment Rate, LNS14000000, Source: U.S. Bureau of Labor Statistics.

Labor force participation: Constructed as the sum of government employment, private employment and the number of unemployed, divided by total population.

Inflation rate: the quarterly growth rate of GDP deflator

Interest rate: FED Funds Rate, Item: FEDFUNDS, Source: FRED.

GDP deflator: Gross Domestic Product, Item 1, Table 1.1.4 Price Indexes for Gross Domestic Product, Source: Bureau of Economic Analysis.

Population: Civilian Noninstitutional Population, Item: LNU00000000, Source: U.S. Bureau of Labor Statistics.

B VAR estimation method

We consider a N-variable VAR model of the following form:

$$\begin{aligned} Y_t &= B(L)Y_{t-1} + u_t \\ u_t &\sim N(0, \Sigma) \end{aligned}$$

The Maximum Likelihood Estimator for (B, Σ) is given by:

$$\begin{aligned}\widehat{B} &= (X'X)^{-1}X'Y \\ \widehat{\Sigma} &= \frac{1}{T}\left(Y - X\widehat{B}\right)'\left(Y - X\widehat{B}\right)\end{aligned}$$

We assume that the prior and posterior distributions of (B, Σ) belong to the Normal-Wishart family:

$$\begin{aligned}\Sigma^{-1} &\sim \mathcal{W}(S^{-1}/\nu, \nu) \\ vec(B) \mid \Sigma &\sim N(vec(B), \Sigma \otimes N^{-1})\end{aligned}$$

with $\mathrm{E}[\Sigma^{-1}] = S^{-1}$. Proposition A.1 on p. 670 in Uhlig (1994) states that if the prior is described by B_o, N_0, S_0 and ν_0, then the posterior is described by B_T, N_T, S_T and ν_T, where:

$$\begin{aligned}\nu_T &= T + \nu_0 \\ N_T &= N_0 + X'X \\ B_T &= N_T^{-1}(N_0 B_o + X'X\widehat{B}) \\ S_T &= \frac{\nu_0}{\nu_T}S_0 + \frac{T}{\nu_T}\widehat{\Sigma} + \frac{1}{\nu_T}(\widehat{B} - B_o)'N_0 N_T^{-1}X'X(\widehat{B} - B_0)\end{aligned}$$

Following Uhlig (2005), we use a weak prior that sets $N_0 = 0$, $\nu_0 = 0$, S_0 and B_0 arbitrary. Flat priors give results that are robust to the reordering of the variables in the VAR.

C Algorithm for shock identification, derivation of IRFs and multipliers

The shock identification follows the approach of Arias et al. (2014), who propose an algorithm for making independent draws from a distribution over the base parameterization that satisfies the zero restrictions (see Algorithm 3 in Arias et al. (2014)). For convenience of the reader, we summarize the basic steps of the algorithm and the subsequent steps for calculating impulse response functions and fiscal multipliers.

Let n be the number of endogenous variables in the VAR and $F(\phi^{-1}(B,\Sigma))$ any function from the base VAR parameterization with dimensions $nr \times n$ that satisfies the condition $F(\phi^{-1}(B,\Sigma,Q)) = F(\phi^{-1}(B,\Sigma,I_n))Q$, for any $Q \in \mathcal{O}(n)$. For instance, $F(\phi^{-1}(B,\Sigma))$ can be a set of impulse response functions or the structural representation matrices. In addition, let Z_j be a matrix $z_j \times nr$ so that $\mathrm{Z}_j F(\phi^{-1}(B,\Sigma,Q))e_j = 0$, where z_j is a number of zero restrictions needed to be imposed on $F(\phi^{-1}(B,\Sigma))$, and e_j is the jth column of the identity matrix I_n. Then, the algorithm is summarized as follows:

1. Draw (B,Σ) from the posterior distribution of the reduced-form parameters as specified in the previous section.

2. Draw $(x_{1,\dots,}x_n)$ independently from a standard normal distribution on $\mathbb{R}^n$.

3. Set
$$Q = \left[\frac{N_1 N_1' x_1}{\|N_1' x_1\|} \quad \dots \quad \frac{N_n N_n' x_n}{\|N_n' x_n\|} \right]$$
where the columns of matrix N_j form an orthonormal basis for the null space of the $(j-1+z_j) \times n$ matrix
$$M_j = \left[\frac{N_1 N_1' x_1}{\|N_1' x_1\|} \quad \dots \quad \frac{N_{i-1} N_{j-1}' x_{j-1}}{\left\|N_{j-1}' x_{j-1}\right\|} \quad \left(Z_j F(\phi^{-1}(B,\Sigma,I_n))\right)' \right]$$
for $1 \leq j \leq n_s$, where n_s is the number of structural shocks considered.

4. Calculate the impulse responses that correspond to the orthogonal matrix Q and save them if the sign restrictions are satisfied.

5. Repeat steps 2-4 for a number of M draws of orthogonal matrices Q.

6. Repeat steps 1-5 for a number of N draws from the posterior distribution of the VAR parameters.

7. For all draws accepted and saved, calculate impulse responses and fiscal multipliers. As in Mountford and Uhlig (2009), fiscal multipliers are computed by dividing the present value cumulative response of output, y, by the present value cumulative response of total government spending, g, after a shock to each spending component, and finally dividing by the average government spending-to-GDP ratio, g/y (see the formula below). The discounting is based on the sample mean nominal interest rate, r.

$$\text{Present value multiplier at horizon h} = \frac{\sum_{j=0}^{h}(1+r)^{-j}y_j}{\sum_{j=0}^{h}(1+r)^{-j}g_j}\frac{1}{g/y}$$

8. Finally, extract the median and the 16^{th} and 84^{th} percentiles of the saved impulse responses and output multipliers.

According to our benchmark identification, zero restrictions are only required to identify the monetary policy shock and they are imposed on the structural representation of the interest rate equation. As a result, in our case $F(\phi^{-1}(B,\Sigma,I_n))$ collapses to the zero-lag structural representation matrix. Furthermore, since the monetary policy shock is the second in order shock identified, then Z_2 is a non-empty matrix, while for the rest shocks with identification order $j=1,3-7$ the matrix Z_j is empty.

D F.O.C. from the household's problem

If we denote by λ_{ct}, λ_{n^pt}, λ_{n^gt}, λ_{ut} the Lagrange multipliers, the first-order conditions of the household's optimization problem are:

[wrt c_t]

$$cc_t^{(1-\eta-\alpha_2)}\alpha_1(c_t)^{(\alpha_2-1)} = \lambda_{ct} \tag{A1}$$

[wrt K^p_{t+1}]

$$\lambda_{ct}\left[1+\omega\left(\frac{K^p_{t+1}}{K^p_t}-1\right)\right]=\beta E_t\lambda_{ct+1}\left\{1-\delta^p+[r^p_{t+1}-\tau_k(r^p_{t+1}-\delta^p)]+\frac{\omega}{2}\left[\left(\frac{K^p_{t+2}}{K^p_{t+1}}\right)^2-1\right]\right\} \tag{A2}$$

[wrt B_{t+1}]

$$\lambda_{ct}\pi_{t+1}=\beta E_t\lambda_{ct+1}R_t \tag{A3}$$

[wrt n^j_{t+1}]

$$\lambda_{n^jt}=\beta E_t\left[\lambda_{ct+1}(1-\tau^n)w^j_{t+1}+\lambda_{n^jt+1}(1-\sigma^j)-U_{l,t+1}\right]\ \text{for } j=p,g \tag{A4}$$

[wrt u_t]

$$\lambda_{n^pt}\psi^{hp}_t+\lambda_{n^gt}\psi^{hg}_t+\lambda_{ct}\varpi=U_{l,t} \tag{A5}$$

where $U_{l,t}\equiv\Phi l_t^{-\varphi}$ is the marginal utility from leisure (labor market non-participation). Equations (A1)-(A3) are standard and include the arbitrage conditions for the returns to private consumption, private capital and bonds. Equation (A4) relates the expected marginal value from being employed to the after-tax wage, the utility loss from the reduction in leisure, and the continuation value, which depends on the separation probability. Equation (A5) states that the value of being search active (rather than non-participating), $\lambda_{ct}\varpi$, plus the expected marginal values of being employed, λ_{n^jt}, weighted by the job finding probabilities, ψ^{hj}_t, should equal the marginal utility from leisure, $U_{l,t}$. The expected marginal value to the household of having an additional member employed in the private sector, $V^H_{n^pt}$, is given by:

$$V^H_{n^pt}=\lambda_{ct}(1-\tau^n)w^p_t-U_{l,t}+(1-\sigma^p)\lambda_{n^pt} \tag{A6}$$

According to (A6), $V^H_{n^pt}$ has the following components: first, the increase in utility given by the real after-tax wage; second, the decrease in utility from lower leisure; third, the continuation utility value, which depends on the separation probability: a private employee will continue having the same job next period with probability $1-\sigma^p$.

Tables

Table 1: Sign restrictions on impulse responses

	shocks						
Restricted variables	$\varepsilon_t^{n^g}$	$\varepsilon_t^{w^g}$	$\varepsilon_t^{c^g}$	$\varepsilon_t^{i_g}$	ε_t^{TR}	ε_t^{MP*}	ε_t^{BC}
Output							+
Private consumption							+
Private investment							+
Inflation rate							
Interest rate							
Government revenue					+		+
Government employment	+						
Government wage rate		+					
Government (non-wage) consumption			+				
Government investment				+			

Notes: All restrictions apply to 0-3 periods after the shock.

ε_t^{ng}: government employment shock, ε_t^{wg}: government wage shock, ε_t^{cg}: government consumption shock, ε_t^{ig}: government investment shock, ε_t^{TR}: government revenue shock, ε_t^{MP}: monetary policy shock, ε_t^{BC}: business cycle shock

*No restrictions on IRFs for the monetary policy shock. Identified through restrictions on the structural representation coefficients of the interest rate equation (see Appendix C).

Table 2: Private output multipliers

	Benchmark VAR			
	Federal		State & Local	
	Ng	Wg	Ng	Wg
T=0	0.59	0.03	2.74	1.76
	[0.07 1.04]	[-1.86 0.60]	[1.74 3.00]	[0.86 2.26]
T=1	0.92	-1.22	1.07	2.34
	[0.01 1.39]	[-3.09 -0.05]	[-2.69 2.40]	[0.76 3.10]
T=2	1.02	-0.59	2.19	2.38
	[-0.08 1.48]	[-2.37 -0.10]	[-1.38 3.60]	[0.60 3.27]
T=3	1.00	0.19	3.09	2.38
	[-0.21 1.55]	[-4.08 4.98]	[0.54 4.11]	[0.49 3.43]
T=4	1.01	0.55	3.47	2.52
	[-0.20 1.57]	[-3.24 8.20]	[1.36 4.46]	[0.42 3.56]
T=5	0.99	0.66	3.52	2.69
	[-0.35 1.57]	[-2.81 7.89]	[1.60 4.49]	[0.30 3.77]

	VAR, controlling for all government levels			
	Federal		State & Local	
	Ng	Wg	Ng	Wg
T=0	1.03	0.34	2.40	1.88
	[0.23 1.36]	[-1.30 1.37]	[1.06 3.67]	[0.62 2.11]
T=1	1.71	-0.37	0.97	2.63
	[0.29 2.04]	[-2.22 -0.03]	[-2.15 2.32]	[0.18 3.29]
T=2	1.83	-0.03	1.79	2.86
	[0.49 2.43]	[-4.33 7.72]	[-1.81 3.07]	[0.41 3.54]
T=3	1.90	0.43	2.55	2.97
	[0.61 2.59]	[-3.78 6.94]	[0.16 3.54]	[0.75 3.63]
T=4	1.96	0.88	2.87	3.06
	[0.64 2.73]	[-2.68 7.12]	[0.32 3.81]	[0.91 3.76]
T=5	1.97	1.05	2.96	3.16
	[0.59 2.80]	[-2.02 7.23]	[0.49 3.95]	[1.21 3.86]

	VAR, Choleski identification			
	Federal		State & Local	
	Ng	Wg	Ng	Wg
T=0	1.05	-0.28	2.99	1.98
	[0.63 1.44]	[-1.09 0.34]	[1.11 5.52]	[1.13 3.15]
T=1	1.82	-2.44	0.75	3.00
	[0.91 3.08]	[-5.04 -0.58]	[-0.99 2.58]	[1.68 4.71]
T=2	2.02	-2.37	1.77	2.55
	[0.92 3.84]	[-6.83 -0.26]	[-0.42 3.84]	[1.06 4.24]
T=3	1.87	-1.52	3.05	2.38
	[0.77 4.09]	[-5.31 2.02]	[0.68 5.05	[0.60 4.06]
T=4	1.68	-0.97	3.53	2.52
	[0.44 3.95]	[-4.55 2.68]	[1.42 5.52]	[0.06 4.31]
T=5	1.60	-0.71	3.53	2.78
	[0.09 4.00]	[-3.89 2.36]	[1.51 5.39	[-0.19 4.83]

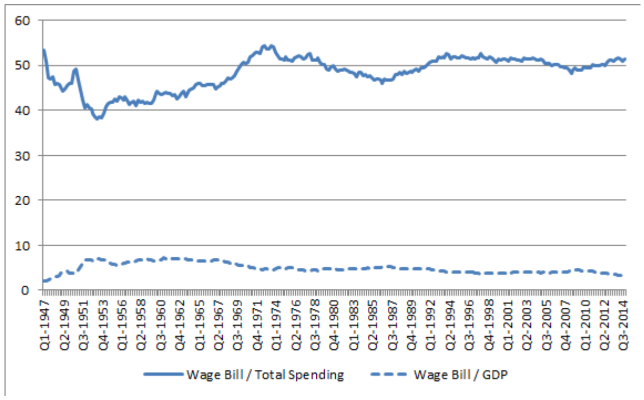
Note: Ng: Government employment shock, Wg: Government wage shock

Table 3: Parameterization

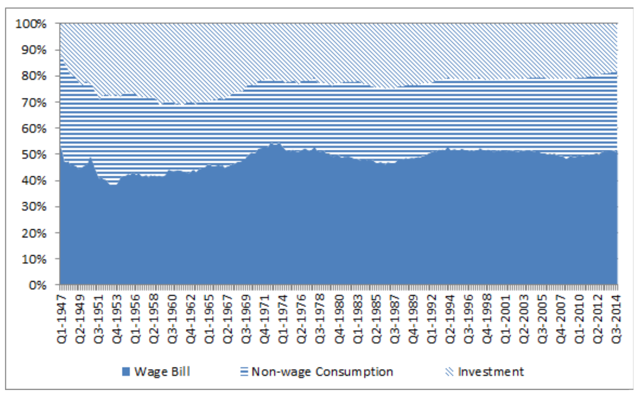
Parameters	Description	Values	Sensitivity Analysis
β	discount factor	0.99	0.99
η	risk aversion coefficient	0.5	0.5
α_1	private consumption share in cc	0.95	[0.85,0.95]
α_2	CES elasticity	-1.95	[-2,-0.5] and [-3,-5]
φ	inverse of Frisch elasticity	1.5	[1,4)
ν	productivity of public goods	0.15	(0,0.2]
ψ	productivity of private capital	0.36	[0.3,0.4]
μ	productivity of public capital	0.1	[0,0,3]
$\frac{K^g}{K^p}$	steady-state capital ratio	0.31	[0.25,0.35]
δ^j	capital depreciation rate	0.025	[0.02,0.03]
ω	adjustment costs parameter	1	[0.1,3]
χ	price stickiness	0.75	[0.55,0.85]
$\frac{\varepsilon}{\varepsilon-1}$	steady-state markup	1.25	[1.1,1.4]
ψ^{fp}	private vacancy filling probability	0.4	[0.3,0.5]
ψ^{fg}	public vacancy filling probability	0.4	[0.3,0.5]
$\frac{\kappa}{w^p}$	vacancy cost - wage ratio	0.045	[0.04,0.05]
$\frac{u}{1-l}$	unemployment rate	0.065	[0.06,0.08]
$\frac{n^g}{n}$	public employment share	0.16	[0.05,0.18]
$\frac{\varpi}{w^p}$	replacement rate	0.45	[0.4,0.5]
$\frac{w^g}{w^p}$	steady-state wage ratio	1.01	[1.005,1.015]
α	matching elasticity	0.6	[0.45,0.65]
$1-l$	labor participation rate	0.65	[0.6,0.7]
σ^g	public separation rate	0.045	[0.045,0.06]
σ^p	private separation rate	0.05	[0.045,0.06]
A	steady-state TFP	1	1
$\overline{ß}$	debt to GDP ratio	0.6*4	2.4
τ^k	capital tax rate	0.2	[0.1,0.4]
τ^n	labor tax rate	0.2	[0.1,0.4]
$\zeta_{ß}$	debt coefficient	-2	[-1,-4]
ζ_π	Taylor's π coefficient	1.5	[1,2.5]
ϱ_g^ψ	persistence of shocks	0.8	[0.1,0.9]
ϱ_R	persistence of interest rate	0.65	[0.4,0.8]

Notes: $j = p, g$, $\psi = \upsilon^g, w^g, c^g$

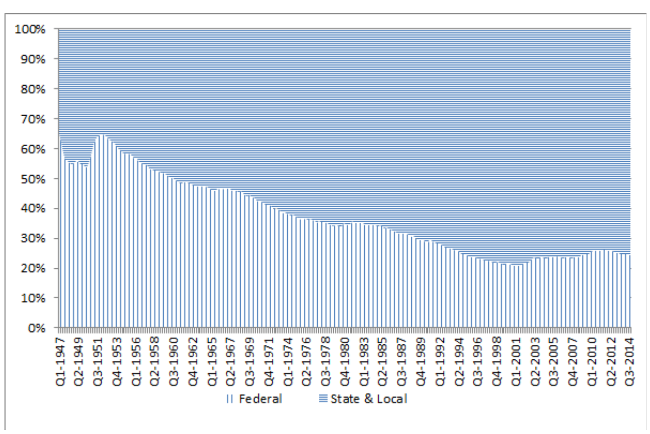
Figures



(a) Historical Evolution

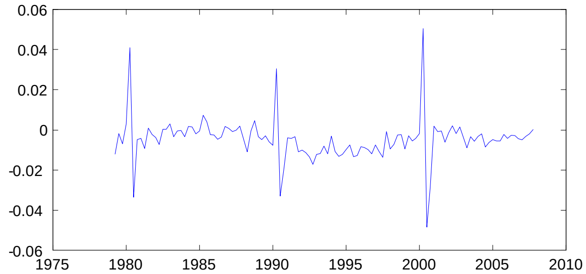


(b) Comparison with the other spending components
(as % of total spending)

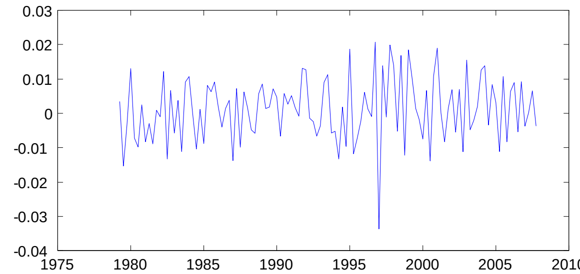


(c) Disaggregation by government level

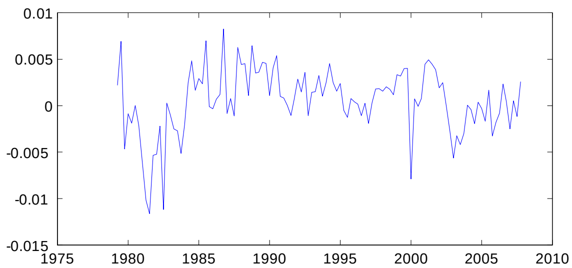
Figure 1: The government wage bill in the U.S. (Data source: BEA)



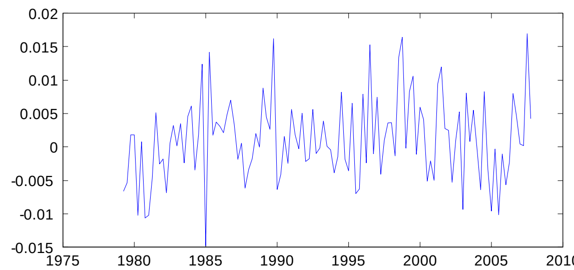
(a) Federal government employment



(b) Federal government wage rate

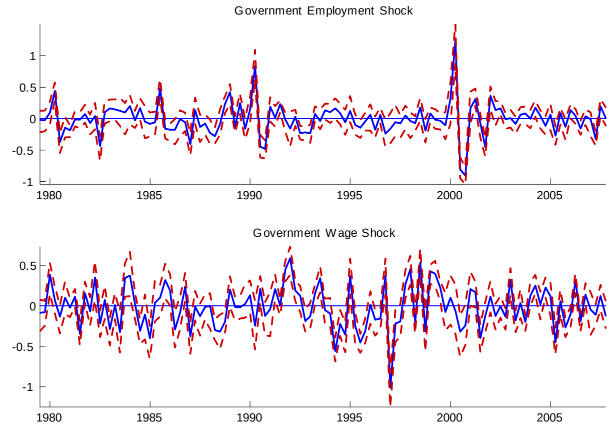


(c) S&L government employment

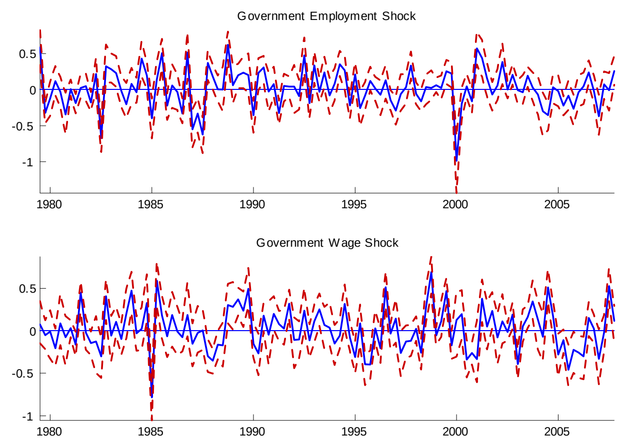


(d) S&L government wage rate

Figure 2: The volatility in U.S. government expenditure series (in growth rates)

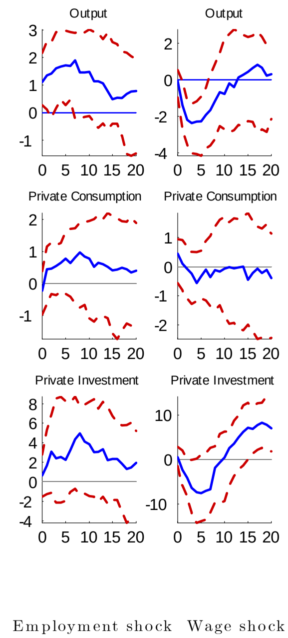


(a) Federal Government

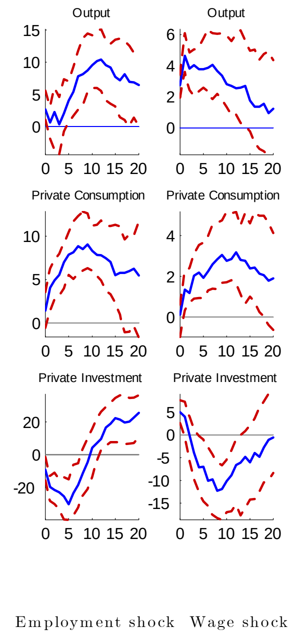


(b) S&L Governments

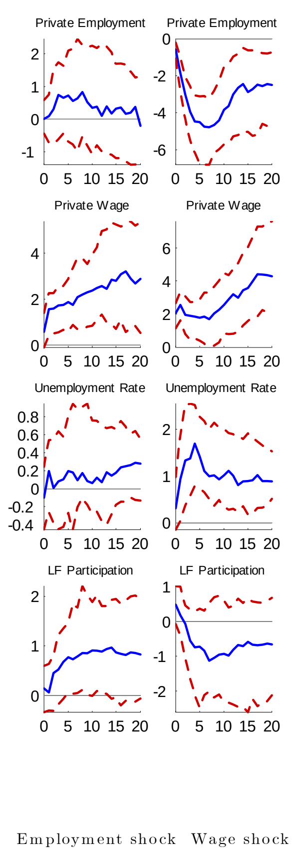
Figure 3: The identified government employment and wage shocks



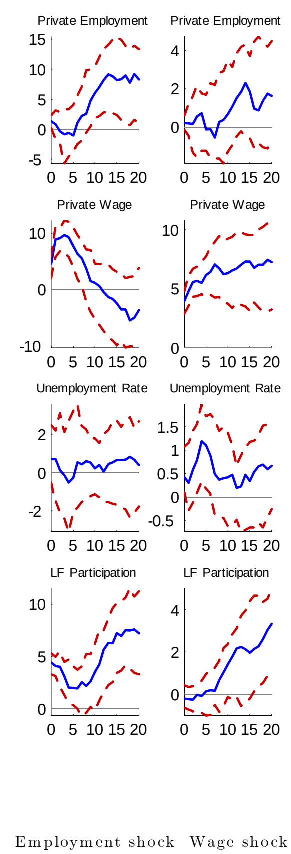
(a) Federal Government



(b) S&L Governments

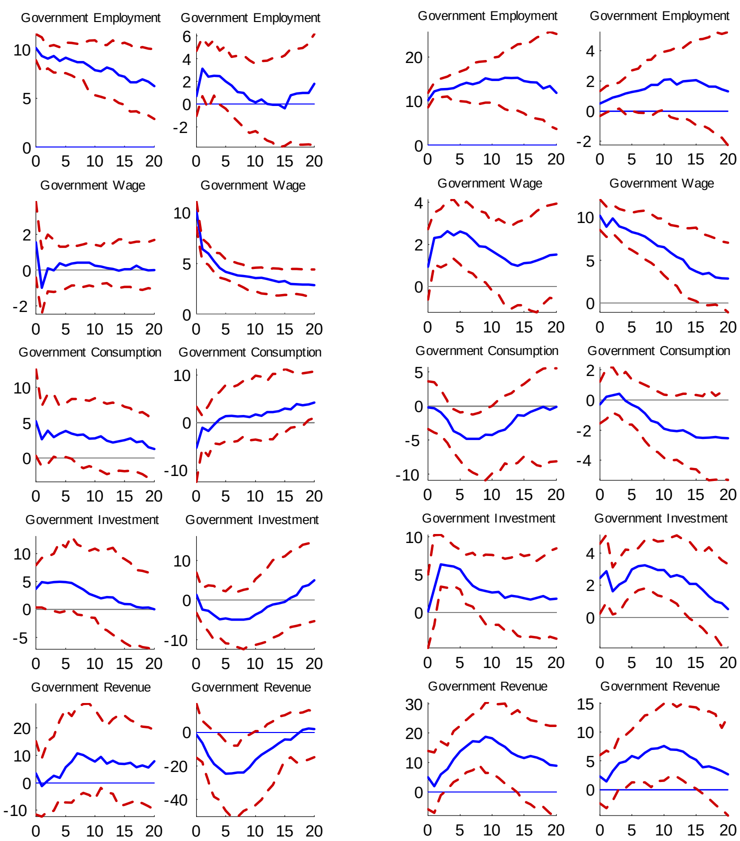


(c) Federal Government



(d) S&L Governments

Figure 4: Impulse responses to government employment and wage shocks



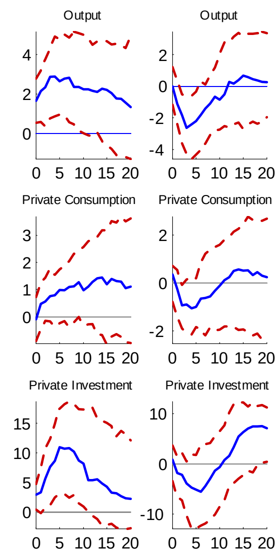
Employment shock Wage shock

(e) Federal Government

Employment shock Wage shock

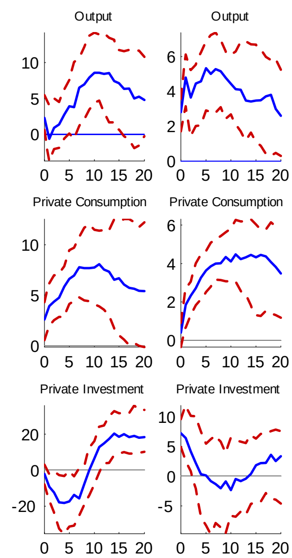
(f) S&L Governments

Figure 4 (cont'd): Impulse responses to government employment and wage shocks



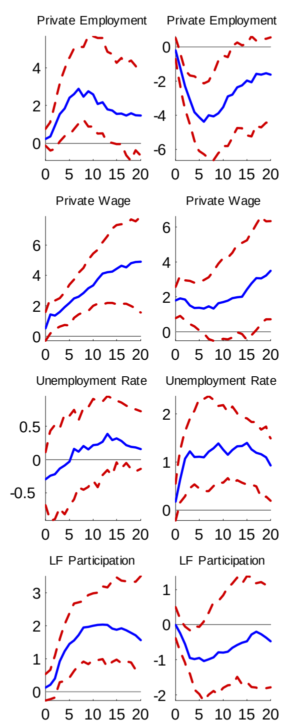
Employment shock Wage shock

(a) Federal Government



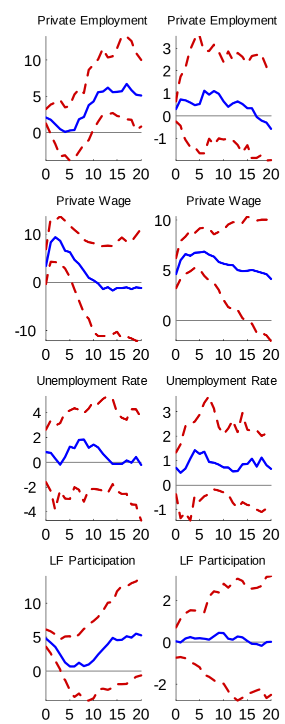
Employment shock Wage shock

(b) S&L Governments



Employment shock Wage shock

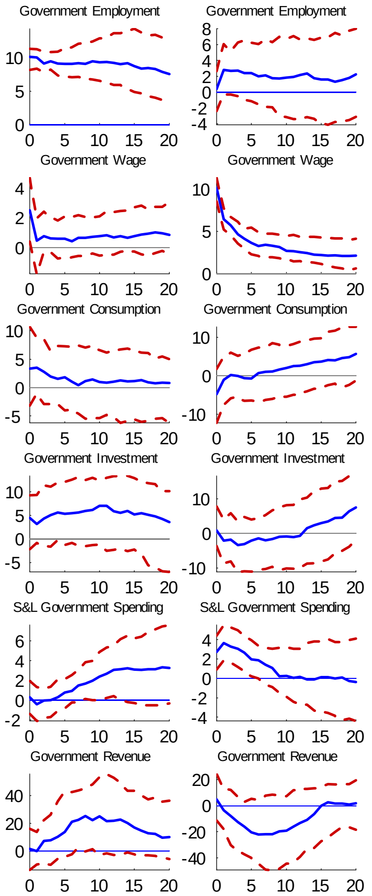
(c) Federal Government



Employment shock Wage shock

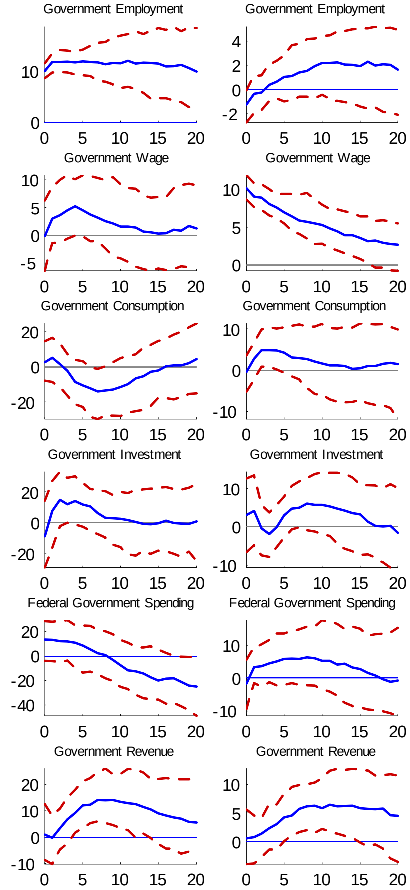
(d) S&L Governments

Figure 5: Impulse responses to government employment and wage shocks, controlling for shocks at all government levels



Employment shock Wage shock

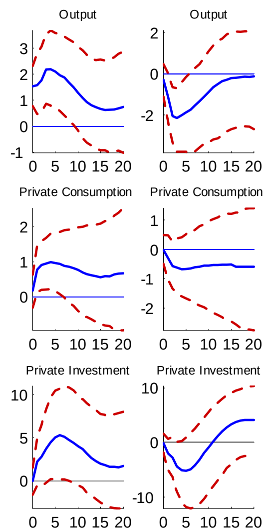
(e) Federal Government



Employment shock Wage shock

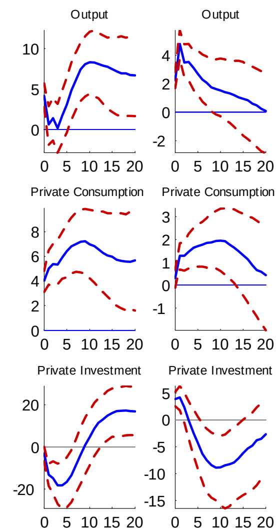
(f) S&L Governments

Figure 5 (cont'd): Impulse responses to government employment and wage shocks, controlling for shocks at all government levels



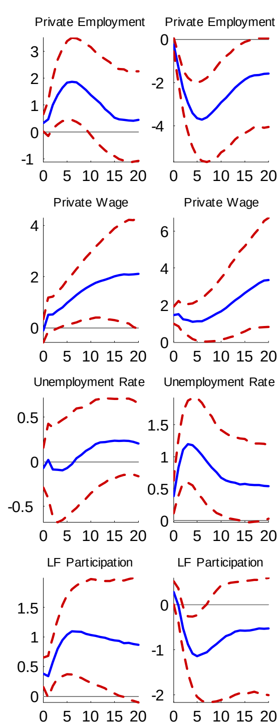
Employment shock Wage shock

(a) Federal Government



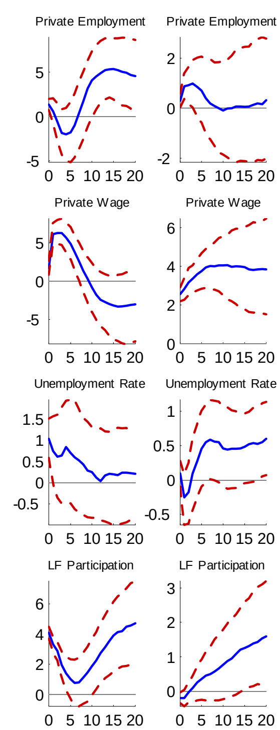
Employment shock Wage shock

(b) S&L Governments



Employment shock Wage shock

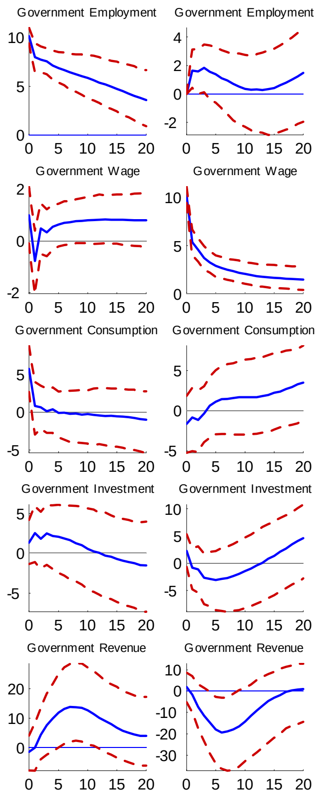
(c) Federal Government



Employment shock Wage shock

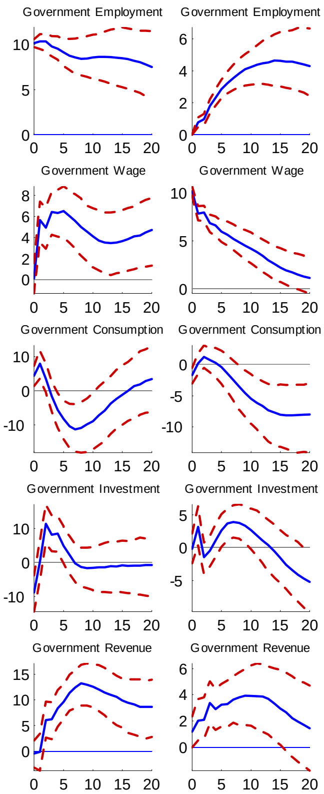
(d) S&L Governments

Figure 6: Impulse responses to government employment and wage shocks, Choleski identification



Employment shock Wage shock

(e) Federal Government



Employment shock Wage shock

(f) S&L Governments

Figure 6 (cont'd): Impulse responses to government employment and wage shocks, Choleski identification

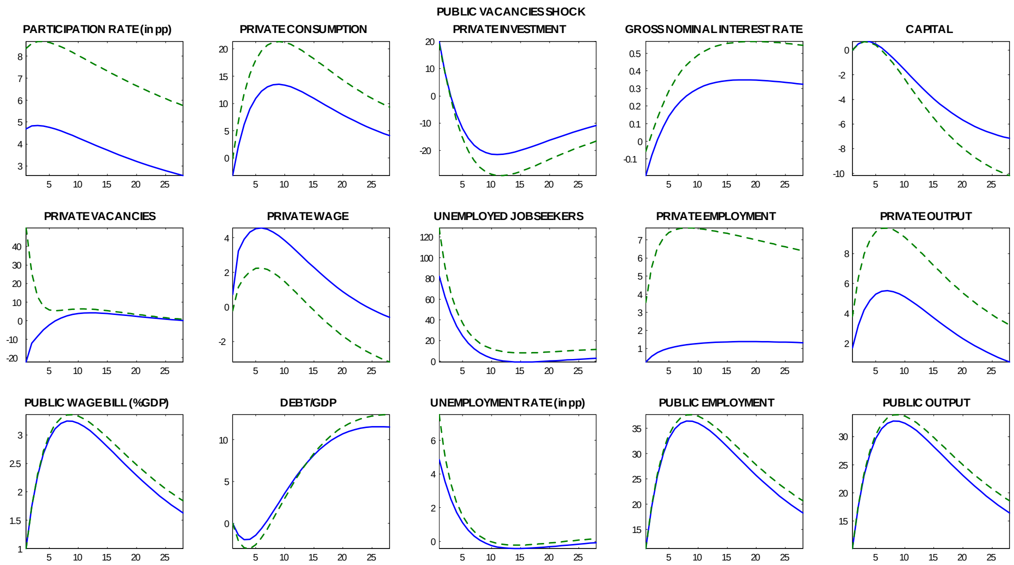


Figure 7a: Theoretical impulse responses to a rise in the public wage bill equal to 1% of GDP induced by a shock to government employment
(solid lines: benchmark calibration, dashed lines: higher degree of complementarity)

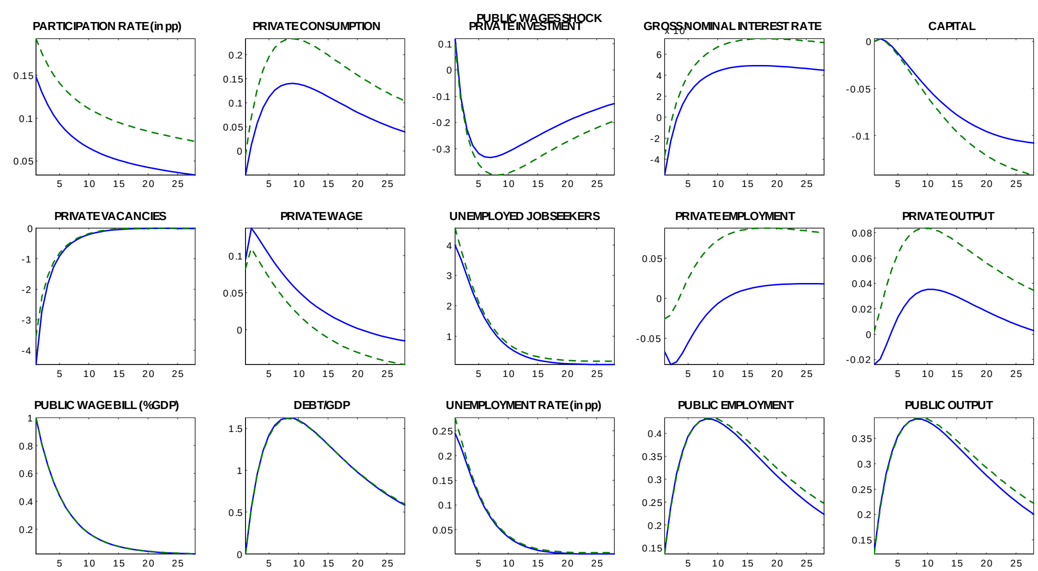
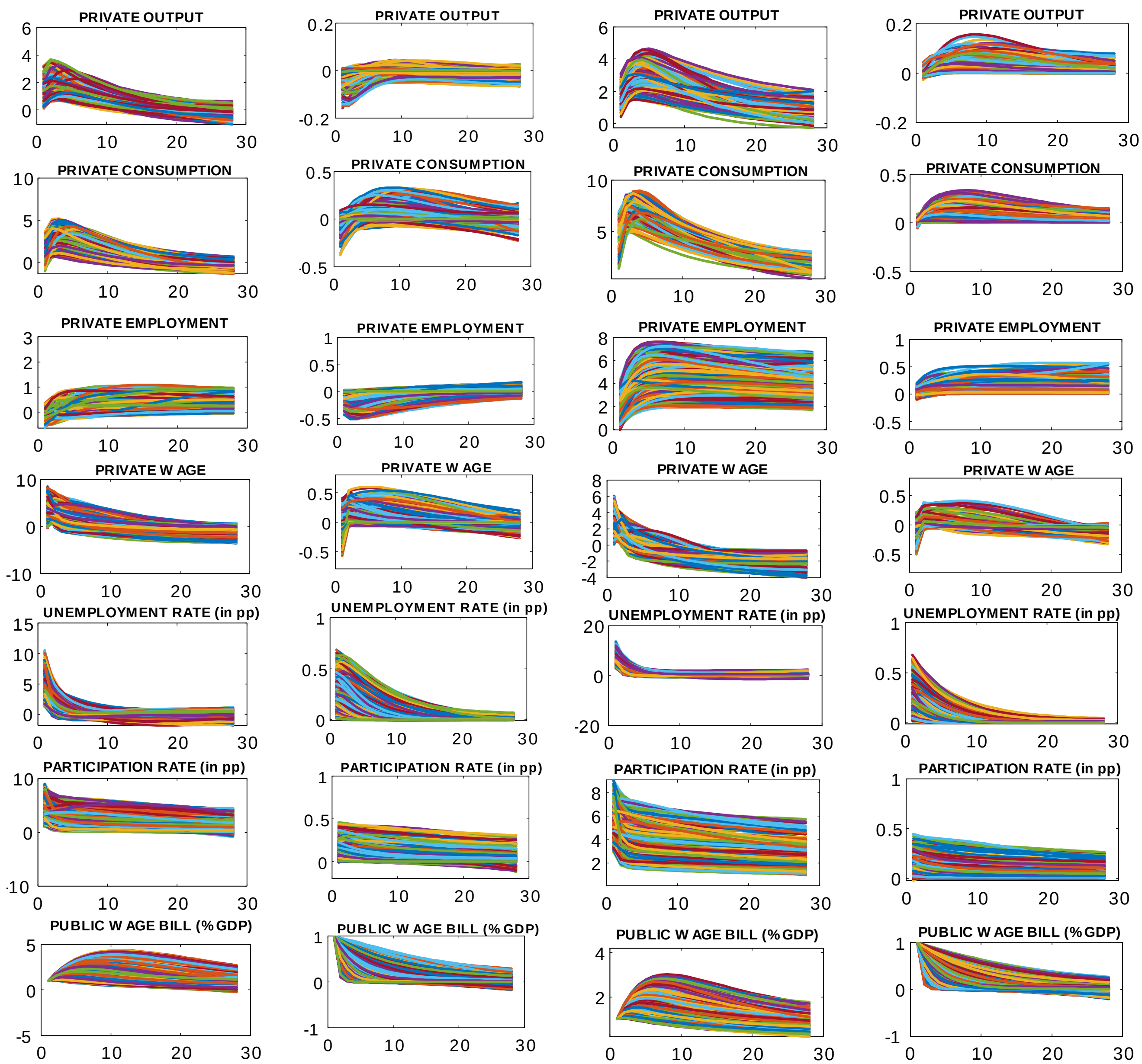


Figure 7b: Theoretical impulse responses to a rise in the public wage bill equal to 1% of GDP induced by a shock to government wages
(solid lines: benchmark calibration, dashed lines: higher degree of complementarity)



(a) Vacancy shock (b) Wage shock (c) Vacancy shock (d) Wage shock

Figure 8: Sensitivity analysis,
Low complementarity (Figures (a) and (b)) against high complementarity (Figures (c) and (d))