The Government Spending Multiplier in a Deep Recession

Jordan Roulleau-Pasdeloup
University of Lausanne

First version : November 2012. This version : April 6, 2017

Abstract

The usual mechanism through which government spending can be effective in increasing GDP in a liquidity trap emphasizes the role of aggregate demand. Higher government spending generates higher inflation, which leads to a lower expected real interest rate. This lower real rate increases aggregate demand. I present new evidence that casts doubt on the empirical relevance of this mechanism. Using the historical U.S dataset assembled in Ramey & Zubairy (2014), I show that the cumulative effect of government spending on inflation at the Zero Lower Bound is significantly *lower* than in normal times. To rationalize this, I build a New Keynesian model with search and matching frictions in the labor market and a downward rigid nominal wage. When solved using global methods, this model generates asymmetric incentives for firms to recruit along the business cycle. This allows the model to match the results reported in Ramey & Zubairy (2014) : the cumulative multiplier effects of government spending on GDP are significantly higher in a recession than in an expansion, although still lower than 1. When augmented with a downward rigid nominal wage, the model is also able to generate a significantly higher multiplier at the zero lower bound with a cumulative effect on inflation that is lower than in normal times. Decomposing the contributions of recession versus liquidity trap dynamics, I find that the latter accounts for only one third of the additional cumulative multiplier effect at the Zero Lower Bound.

Keywords: Zero lower bound, New Keynesian, Government spending multiplier, Search and Matching Frictions.
JEL Classification: E24, E31, E32, E52, E62

Acknowledgments I would like to thank my PhD advisor, Florin O. Bilbiie, for his support. I would also like to thank Julien Albertini, Vincent Boitier, Pierre Cahuc, Edouard Challe, Francois Fontaine, Basile Grassi, Christian Haefke, Jean-Olivier Hairault, Robert E. Hall, Tommaso Monacelli, Julien Prat, Anastasia Zhutova and various seminar participants for helpful comments. A special thank goes to Antoine Lepetit for extensive comments on this paper. Finally, I want to thank various anonymous referees for their detailed suggestions that greatly improved the quality of the paper.

1 Introduction

Six years after the American Recovery and Reinvestment Act (ARRA) has been passed, the debate about government spending multipliers is still lively among academics. The main question that is being asked is the following : can temporarily higher government spending boost the economy in a downturn? The standard way to measure the effectiveness of such a policy is to see if it is successful at raising GDP more than proportionally; in other words : to see if the government spending multiplier is large.[1] On this subject, there is mounting empirical evidence pointing towards bigger government spending multipliers in periods of recession. Using non-linear Vector Auto-Regression methods, Bachmann & Sims (2012) and Auerbach & Gorodnichenko (2012) show that the government spending multiplier is higher (as high as 2) when some measure of the output gap is higher than usual. Ramey & Zubairy (2014) find evidence for larger multipliers in times of slack, but those are still lower than unity.[2] They also provide some evidence for higher multiplier effects of government spending when the economy is in a liquidity trap (see also Almunia et al. (2010) who focus on the liquidity trap episode in the Great Depression). One of the main results of this literature is that an exogenous increase in government spending seems to have little if no effect on inflation. This finding is confirmed in a recent paper by Dupor & Li (2015), in which they show that the ARRA did not cause a rise in expected inflation.[3] I complement these studies and analyze the effects of government spending on inflation at the Zero Lower Bound. Using the data assembled in Ramey & Zubairy (2014), I document that the cumulative effect of government spending on inflation is actually significantly *lower* at the Zero Lower Bound than in normal times.

Theoretically, aside from a few attempts to explain why the multiplier might be higher in a recession than in an expansion,[4] most of the papers on this subject have been focused on episodes where the Zero Lower Bound (ZLB henceforth) is a binding constraint.[5] The mechanism that is typically put forward in those papers is the following : by increasing inflation through higher government spending, the government can reduce the real interest rate since the nominal rate is pinned at zero. This will induce people to consume more

[1]Many papers have tried to estimate the multiplier effects of government purchases, among which Blanchard & Perotti (2002), Perotti (2008), Barro & Redlick (2011) and Ramey (2011).

[2]In a meta-analysis of over 98 studies, Gechert & Rannenberg (2014) find that government spending multipliers are significantly higher in recessions. Looking at local multiplier effects, Nakamura & Steinsson (2014) and Shoag (2016) also find evidence for larger multipliers in times of slack.

[3]In a recent paper, Miyamoto et al. (2015) present evidence of larger multipliers at the ZLB which are associated with zero impact on expected inflation, but a significantly positive cumulative effect on expected inflation. Focusing on unemployment benefits extensions in the U.S during the Great Recession, Hagedorn et al. (2013) find that these had a stimulative effect at the local level without generating an increase in measured marginal costs/inflation.

[4]Canzoneri et al. (2016), building on a model à la Curdia & Woodford (2010), show that counter-cyclical financial frictions can make government spending quite effective during recessions, all the more so when it is financed by debt. Focusing on the labor market, Michaillat (2014) shows that increasing public employment has a larger effect on total private employment in a recession than in an expansion. The reason is that since there is job rationing in a recession and the labor market tightness is low, public employment has a low crowding out effect on private employment in a recession.

[5]See Eggertsson (2011), Woodford (2011), Christiano et al. (2011) or Werning (2011).

today, generating more inflation and thus more consumption. At the end of this virtuous cycle stands a GDP multiplier roughly three times as large as in normal times (Christiano et al. (2011)). Most of these papers use a New-Keynesian model in which prices are set as a markup over current and future expected marginal costs and labor is hired on a frictionless spot market.

However, I show that this model (even using the full, non-linear solution) has two serious shortcomings. First, it cannot reproduce the observed asymmetric effects of government spending over the cycle. Given that a Zero Lower Bound episode does not always bind in a recession, but is almost always the *consequence*[6] of a recession, it is important to understand the behavior of the economy in a recession since it will shape the dynamics of the model at the Zero Lower Bound. Second, this model relies extensively on an expected inflation channel that has no support in the data. In this paper, I provide additional evidence to this effect. The cumulative effect on inflation is significantly lower at the ZLB. Under some specifications, it is also the case in periods of slack.

My objective in this paper is then to develop a model that can generate both (i) asymmetric effects of government spending over the cycle qualitatively consistent with the data and (ii) a significantly higher GDP multiplier at the zero lower bound coupled with a lower reaction of inflation. To do so, I will focus on the one building block that has been often neglected in the previous literature : the labor market. I do not need to provide a figure showing that unemployment usually rises in a recession. Surprisingly, few papers explicitly discuss the dismal state of the labor market in the mainstream literature about the impact of government spending at the ZLB.[7] One might then wonder : is it really this important? In this paper, I argue that the answer is yes.

The reason for this can be succinctly described as follows. Empirical evidence tends to show that labor market adjustment occurs largely through the extensive margin in a recession (see van Rens (2012)). A candidate explanation for this is that since there are a lot of idle resources in recessions, it is easier to recruit in those situations. It follows that higher demand from the government during a recession —and *a fortriori* when the ZLB binds—is likely to be met with higher employment instead of higher real wages.

I show that a New Keynesian model with search and matching frictions in the labor market and flexible real wages is consistent with this intuition. Because there is a large pool of unemployed people in a recession, firms do not have to post many vacancies to recruit in

[6]In fact, it has been a binding constraint only three times in recent history : in most of developed countries during the Great Depression, in the United States and Euro Zone in the Great Recession and in Japan during the "Lost Decade(s)". Three periods which are associated with severe recessions.

[7]Notable exceptions include Hall (2011b), Hall (2011a) and Albertini & Poirier (2014). Hall (2011b) uses a DSGE model with a frictional labor market, heterogeneous households and (exogenous) sticky prices. He shows that an overhang following a debt-fueled housing binge coupled with the zero lower bound can generate a "long slump". Hall (2011a) develops a simple model and point to promising models that can resolve the conflict between unemployment as a result of i) frictional labor markets and ii) the level of product demand. The model I will develop in this paper belongs to the class of models that Hall (2011a) deems as promising to study unemployment dynamics at the Zero Lower Bound. Finally, Albertini & Poirier (2014) use a New Keynesian model with search and matching frictions on the labor market to study the effects of unemployment benefits extensions at the Zero Lower Bound.

order to meet the increase in aggregate demand coming from government spending. As a result, employment (and GDP) effects of fiscal policy are going to be higher in a recession. What is crucial to capture this asymmetry is to solve the model using global solution methods. Indeed, the probability to fill a vacancy is a convex function of labor market tightness : as such, it increases markedly in recessions.[8] With first-order perturbation methods, the policy rules are necessarily linear and entirely miss this feature so that an increase in government spending has the same effect in recessions and expansions. In contrast, by using a global solution method, I am able to capture this asymmetry.

While the model with flexible wages does a good outside the ZLB, it mostly does a bad one when this constraint is binding. First, when a large shock sends the economy at the Zero Lower Bound, the economy experiences a relatively large deflation, which is at odds with what we observed during the recent recession. Then, while the model does deliver an impact multiplier of around 1.4 at ZLB, this is accompanied by a cumulative increase in inflation that is significantly larger than in normal times. These two features are clearly at odds with the data.

I show that these shortcomings can be tied to the assumption that real wages are perfectly flexible in this model. To the contrary, many papers document the presence of downward wage rigidity.[9] Accordingly, I add a downward rigid nominal wage to the model with a frictional labor market, which implies that the *real* wage is also downward rigid.

Following a negative demand shock, inflation will decrease and the real wage will increase as a consequence.[10] A government spending shock, generating inflation because more resources have to be used to produce more, will tend to lower the real wage. Since this latter usually accounts for a large share of marginal costs, inflation will react less than in normal times, triggering only a modest decrease in the real interest rate. As a consequence, this version of the model is able to generate a significantly higher multiplier at the zero lower bound, and does so with a cumulative increase in inflation that is lower than in normal times, as in the data. In line with the previous literature, the model says that government spending is more effective at the Zero Lower Bound. However, it emphasizes another mechanism : government spending has higher multiplier effects at the ZLB not only because it generates inflation, but because it is relatively easier for firms to recruit in a deep recession. It follows that the GDP multiplier at the ZLB conflates two effects : the fact that the recession is large and the labor market equilibrium is far from its steady state and monetary policy is not responsive anymore. Having a model that can generate both effects, I study a decomposition of the multiplier at the ZLB. I find that the role of unresponsive monetary policy explains 42% of the additional multiplier effect at ZLB for an impact multiplier of 1.27. For cumulative multipliers, the share explained by unresponsive monetary policy falls to 32%.

[8] Petrosky-Nadeau & Zhang (2013) develop a similar argument in a RBC model with search and matching frictions on the labor market driven by technology shocks.

[9] Rendahl (2014) presents evidence that the Employment Cost Index deflated by the price deflator for Personal Consumption Expenditures experienced a sharp increase during the 2008-2009 recession while its nominal counterpart barely budged. Bernanke & Carey (1996) provide similar evidence for the Great Depression. See also Schmitt-Grohé & Uribe (2012b) and the references therein.

[10] Daly et al. (2012) show that this is what happened during the Great Recession.

This paper is closely related to two recent contributions. Michaillat (2014) also focuses on the labor market to understand government spending multipliers over the cycle. He shows that a model with search and matching frictions coupled with wage rigidities gives more power to fiscal policy in recessions. However, my paper differs from his in many important dimensions. First, I present empirical evidence for the effect of government spending increases recessions and at the ZLB that I use to discipline the model. Also, I show that wage rigidity is not necessary to generate asymmetric effects on GDP from fiscal policy over the cycle. In addition, he does not look at the impact of government spending in a liquidity trap. What I will show in this paper is that it is important to understand what happens in recessions to get reliable predictions at the ZLB. Rendahl (2014) develops a similar model, albeit with flexible prices and a constant nominal wage. He focuses on the amplification properties of labor market frictions exclusively at the ZLB in a linear setup. As such, his model is silent about the different effects of government spending in recessions versus expansions outside the ZLB. As a result, in his model all the additional multiplier effect at the ZLB comes from unresponsive monetary policy. His model also implies that inflation reacts more after a government spending shock and that expected inflation reacts less at the ZLB compared with what happens in normal times. I do not find much empirical support for these predictions. On a technical level, none of these two papers deals with the global solution of the non-linear model with stochastic shocks as I do here.

I first describe in section 2 the usual mechanism through which one obtains a higher than normal multiplier at ZLB in the context of a simple New Keynesian model. I then show that it implies a behavior of main macroeconomic variables at odds with empirical evidence. In section 3 , I develop a New Keynesian model with search and matching frictions and a downward nominal wage. I also present the calibration and solution algorithm. In section 4, I analyze the quantitative results of the model under different calibrations.

2 High multipliers in the standard New Keynesian model and empirical evidence

The standard New Keynesian model has been widely used to frame discussions about the impact of government spending policies. In contrast to the standard RBC model, it emphasizes the role of monetary policy in shaping the response of the economy to a government spending shock. When the economy is not in a recession, this makes little difference as both model predicts that the multiplier will be lower than 1. As monetary policy becomes more and more accomodative however, the New Keynesian model predicts higher multiplier effects. The ZLB is an extreme case in which monetary policy does not react to inflation. It follows that if government spending increases at the ZLB, inflation is going to decrease the real interest rate and prompt households to consume more, which will put further upward pressure on inflation. This generates a multiplier effect that is much higher than in normal times—see Eggertsson (2011) and Christiano et al. (2011). Since these papers rely on a simple two-state Markov process to derive analytical solutions, expected inflation will be the same all along during the liquidity trap. This simplification however masks some potentially important features. Virtually all New Keynesian models feature an Euler Equation at their core. Assuming log utility and separable preferences over consumption and leisure, taking a log-linear approximation and iterating forward, this equation usually takes the following form:

$$c_t = -\mathbb{E}_t \sum_{k=0}^{\infty} (i_{t+k} - \pi_{t+k+1}) + \text{t.i.p},$$

where c_t is private consumption, π_t is price inflation and t.i.p stands for *terms independant of policy*. Let us assume that a sufficiently large shock generates a ZLB episode that lasts T periods. Then, the Euler equation becomes:

$$c_t = \mathbb{E}_t \sum_{k=0}^{T} \pi_{t+k+1} - \mathbb{E}_t \sum_{k=T+1}^{\infty} (i_{t+k} - \pi_{t+k+1}) + \text{t.i.p}, \tag{1}$$

This equation shows that it is the cumulative effect on inflation that is important to generate an increase in private consumption, and thus an impact multiplier that is higher than 1. Even if inflation where to decrease in period $t+1$, if this is more than compensated by a subsequent, persistent increase, consumption would be crowded in. The main takeaway from this is that it is not enough to look at the impact of government spending on expected inflation, one has to look at the cumulative impact on inflation from period $t+1$ onwards. This is what motivates the empirical strategy in the next subsection. In the standard New Keynesian model, a *persistent* increase in government spending will generate a persistent increase in inflation. From equation (1), this can generate high multiplier effects on GDP/consumption.

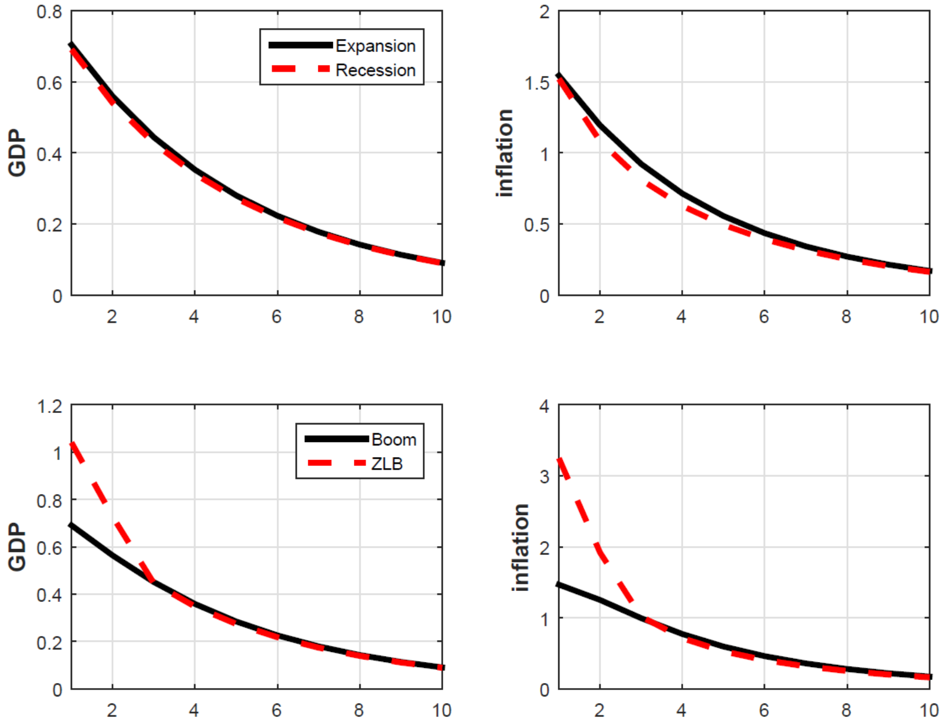
While the larger multiplier effect of government spending has received support from the data (Almunia et al. (2010) and Miyamoto et al. (2015)), this relies on a substantial rise in cumulative expected inflation that does not seem to be present in the data.

Furthermore, the standard New Keynesian model behaves very much the same in expansions and recessions. This is obviously true when the model is solved using first-order perturbations methods, as is done in the majority of cases. That being said, the standard New Keynesian model has many sources of non-linearity : (potentially) quadratic adjustment costs, a utility function that is concave in consumption and labor *etc.* However, in the rare cases where the model has been solved using global methods, it only displayed a minimal degree of asymmetry between expansions and recessions (see Fernández-Villaverde et al. (2015)). To confirm this, I study a global solution of a standard New Keynesian model[11] using a Parameterized Expectations Algorithm as in Albertini et al. (2014).

One crucial parameter in this model is the Frisch elasticity of labor supply, as it determines the elasticity of real marginal cost (and thus, inflation) to a government spending shock. In the following simulations, I use the standard value of $\varphi = 1$ for this parameter. Additional simulations for different values as high as $\varphi = 4$ give similar results and are reported in Figure 9 (in the Appendix). I study here the impact of a government spending shock in a mild recession and a large recession with a binding Zero Lower Bound. Both arise

[11]The model is similar to the one developed in Albertini et al. (2014). See the appendix for a summary of the model equations.

Figure 1: Effects of a 1% increase in government spending, standard New Keynesian model.



Notes: The black line represents the difference between the path of GDP/inflation (in annual terms) with i) only a positive preference shock and ii) a preference and government spending shock. This difference is then scaled by the initial increase in government spending, so that the response is the multiplier effect of government spending. The red dashed line represents the same but with a negative preference shock.

following a discount factor shock. In each case, the expansion/boom scenario is given by the same discount factor shock of the opposite sign. In Figure 1, I plot the multiplier effects on GDP and (annual) inflation of a 1% increase in government spending.

One can see from Figure 1 that the model does not display a large degree of asymmetry between recessions and expansions when the ZLB is not a binding constraint. The reaction of GDP and inflation is only marginally lower in a recession. This comes from the fact that real marginal cost is lower after a negative aggregate demand shock. As a consequence, a given increase in government spending has a proportionally larger effect in this case. In turn, this comparatively larger reaction of marginal cost and inflation calls for a more aggressive reaction by the central bank. In equilibrium, the increase in interest rate is such that private consumption and inflation are both lower than in a boom.

When the central bank is unable to react however, this larger inflation reaction generates a decrease in the expected real interest rate which prompts a further increase in private consumption, generating a virtuous cycle. What is key at the ZLB is that the increase in government spending has a positive effect on cumulative expected inflation. In this experiment, the economy stays at the ZLB for 2 periods, private consumption is crowded in in the first period and so the GDP multiplier is (slightly) larger than 1.

To summarize, while government spending is more effective at the ZLB, it is not the case in a standard recession. In this case, a government spending shock has a marginally lower effect on inflation and GDP. To see whether this is borne out by the data, I will follow Ramey & Zubairy (2014) (henceforth RZ) and estimate government spending multipliers on historical U.S data.

2.1 Confronting the Standard Model with Empirical Evidence

To evaluate the effect of government spending increases in recessions and at the ZLB, I use the empirical strategy laid out in RZ, which is based on local projection methods developed in Òscar Jordà (2005). RZ argue that measuring the multiplier as a the peak response of output/inflation to the initial increase in government spending potentially generates an upward bias. Accordingly, I focus on the cumulative multiplier effects of government spending across different regimes. I use the codes provided by the authors and estimate the following two equations:

$$\sum_{j=0}^{h} z_{t+j} = \gamma_h + \phi_h(L)X_{t-1} + m_h \sum_{j=0}^{h} g_{t+j} + \omega_{t+h} \tag{2}$$

$$\begin{aligned}\sum_{j=0}^{h} z_{t+j} = {} & I_{t-1}\left[\gamma_{A,h} + \phi_{A,h}(L)X_{t-1} + m_{A,h}\sum_{j=0}^{h} g_{t+j}\right] \\ & + (1 - I_{t-1})\left[\gamma_{B,h} + \phi_{B,h}(L)X_{t-1} + m_{B,h}\sum_{j=0}^{h} g_{t+j}\right] + \omega_{t+h}\end{aligned} \tag{3}$$

where z is the variable of interest, $\mathcal{I}$ is a dummy variable that indicates if the economy is in a recession/expansion state when the shock hits, X is a vector of control variables and g is a measure of government spending. While RZ focus on GDP for the variable z, I complement their analysis and study the impact on inflation. As in their paper, the quarterly measure of inflation is the growth rate of the GDP deflator. Depending on the specifications, the vector of control variables contains a measure of tax divided by GDP and deterministic trends.

The maximum horizon is 5 years, so that $h = 1 \ldots 20$. Equations 2 and 3 are estimated for each value of h on the sample from 1889 to 2015. I concentrate on the estimated value of m_h (for the linear case) and the difference between $m_{A,h}$ and $m_{B,h}$ for the case when the impact of government spending is allowed to be different across states. RZ study many specifications with respect to the variable used to instrument government spending. While they show that the Defense News variable is likely to be more exogenous than the Blanchard & Perotti (2002) shock, the latter seems to be a more relevant instrument in the short run. Accordingly, I report the results using both shocks as well as for the specification in which they simultaneously use both of those two shocks as instrument in Tables 1 and 2. I follow RZ and report the p-value associated with the test of significant difference in multipliers across regimes. I report their preferred ones, which are heteroscedastic- and autocorrelation-consistent (HAC) p-values. I begin with the results for the case in which the economy exhibits some slack; as in RZ, I report cumulative multipliers at both 2 and 4-year horizons.

Following RZ, there is slack in the economy when the unemployment rate is higher than 6.5%. One can see from Table 1 that the cumulative multiplier effects on GDP are usually significantly higher when the economy exhibits slack.[12] Regarding inflation, the cumulative multiplier effect is always lower in times of slack, although this difference is never significant.

The main goal of this paper is to understand the mechanisms behind the multiplier effects of government spending when the recession is so deep that the ZLB becomes a binding constraint. Accordingly, I now report the cumulative government spending multipliers when the economy is at the ZLB versus in normal times. As already stated, special attention will be devoted to the cumulative impact on inflation as it is a main driver behind the supposedly large effects of government spending at the ZLB.

From Table 2, one can see that the cumulative multiplier effect on GDP is usually significantly larger than in normal times.[13] The multiplier effect at ZLB is lower than 1 though. It should be kept in mind however, that usually the discussion is about *impact* multipliers. In a standard New Keynesian model, it is very much possible to have an impact multiplier larger than 1 associated with a cumulative multiplier that turns out to be lower than unity.[14] For instance, this is more likely to be the case if (i) government spending is very persistent and/or (ii) the ZLB spell is short. These two features imply that a good share of the increase in government spending occurs once the economy is out of the ZLB, so that the overall cumulative multiplier effect is reduced.

The fact that cumulative GDP multipliers are usually higher in times of slack / ZLB can also be found in RZ. The novel empirical finding that I document here is that the cumulative multiplier effect on inflation is again always lower in a deep recession, which is now associated with a binding ZLB. This time however, the difference between normal times and ZLB periods is statistically very significant, except for the the Blanchard & Perotti (2002) shock at a long horizon. This is in sharp contrast with the various papers that have studied the multiplier effects of government spending in various New Keynesian environments. In these models, the cumulative effect on inflation is significantly *higher* at the ZLB than in normal times.[15] As this is the main empirical result of this paper, I plot in Figure 2 the paths of $m_{A,h}$, $m_{B,h}$ and m_h (along with 95% confidence bands) for GDP and inflation. As Figure 2

[12]The results are similar if slack is measured as a deviation of unemployment from its HP trend. As it stands, slack states also incude periods where the ZLB is binding. Results are mixed and much less precise when leaving out these latter as most large variations in government spending arise when the ZLB is binding. As such, multipliers in times of slack will be a combination of multipliers in times of slack and during the ZLB.

[13]This is true except for the case with Military News Shocks. However, as RZ show, this shock as the lowest relevance at the ZLB. The best one by this metric is the instrument that combines both shocks.

[14]See Roulleau-Pasdeloup (2016) for an example. This is also going to be the case for the model with downward wage rigidity developed in section 3.

[15]In a recent contribution, Rendahl (2014) develops a model in which an increase in government spending at the ZLB has a negative effect on expected inflation. In addition, his model predicts that the initial increase in inflation is much higher at the ZLB than in normal times. I do not find evidence for this pattern in the data. Other contributions (see for example Kiley (2016)) using sticky information models in the vein of Mankiw & Reis (2002) show that government spending has low multiplier effects at the ZLB. This is associated with a cumulative effect on inflation that is negative. Again, this stands in sharp contrast with the results presented here.

Table 1: Estimates of GDP/Inflation Multipliers Across States of Slack

GDP

	Linear Model	Expansion	Recession	P-Value
Military News Shock				
2 year Integral	0.66 (0.06)	0.59 (0.09)	0.6 (0.09)	0.95
4 year Integral	0.71 (0.04)	0.67 (0.12)	0.68 (0.05)	0.92
Blanchard Perotti Shock				
2 year Integral	0.38 (0.11)	0.3 (0.11)	0.68 (0.1)	0.005***
4 year Integral	0.47 (0.11)	0.35 (0.11)	0.77 (0.08)	0.001***
Combined				
2 year Integral	0.42 (0.1)	0.33 (0.11)	0.62 (0.098)	0.098*
4 year Integral	0.56 (0.08)	0.39 (0.11)	0.68 (0.05)	0.02**

Inflation

	Linear Model	Expansion	Recession	P-Value
Military News Shock				
2 year Integral	0.31 (0.11)	0.52 (0.24)	0.2 (0.06)	0.22
4 year Integral	0.14 (0.1)	0.44 (0.25)	0.06 (0.03)	0.13
Blanchard Perotti Shock				
2 year Integral	0.002 (0.1)	0.05 (0.16)	0.02 (0.09)	0.9
4 year Integral	0.05 (0.06)	0.17 (0.08)	-0.026 (0.07)	0.14
Combined				
2 year Integral	0.05 (0.11)	0.06 (0.19)	0.09 (0.13)	0.91
4 year Integral	0.12 (0.1)	0.25 (0.16)	0.06 (0.03)	0.26

Table 2: Estimates of GDP/Inflation Multipliers Across Monetary Regimes

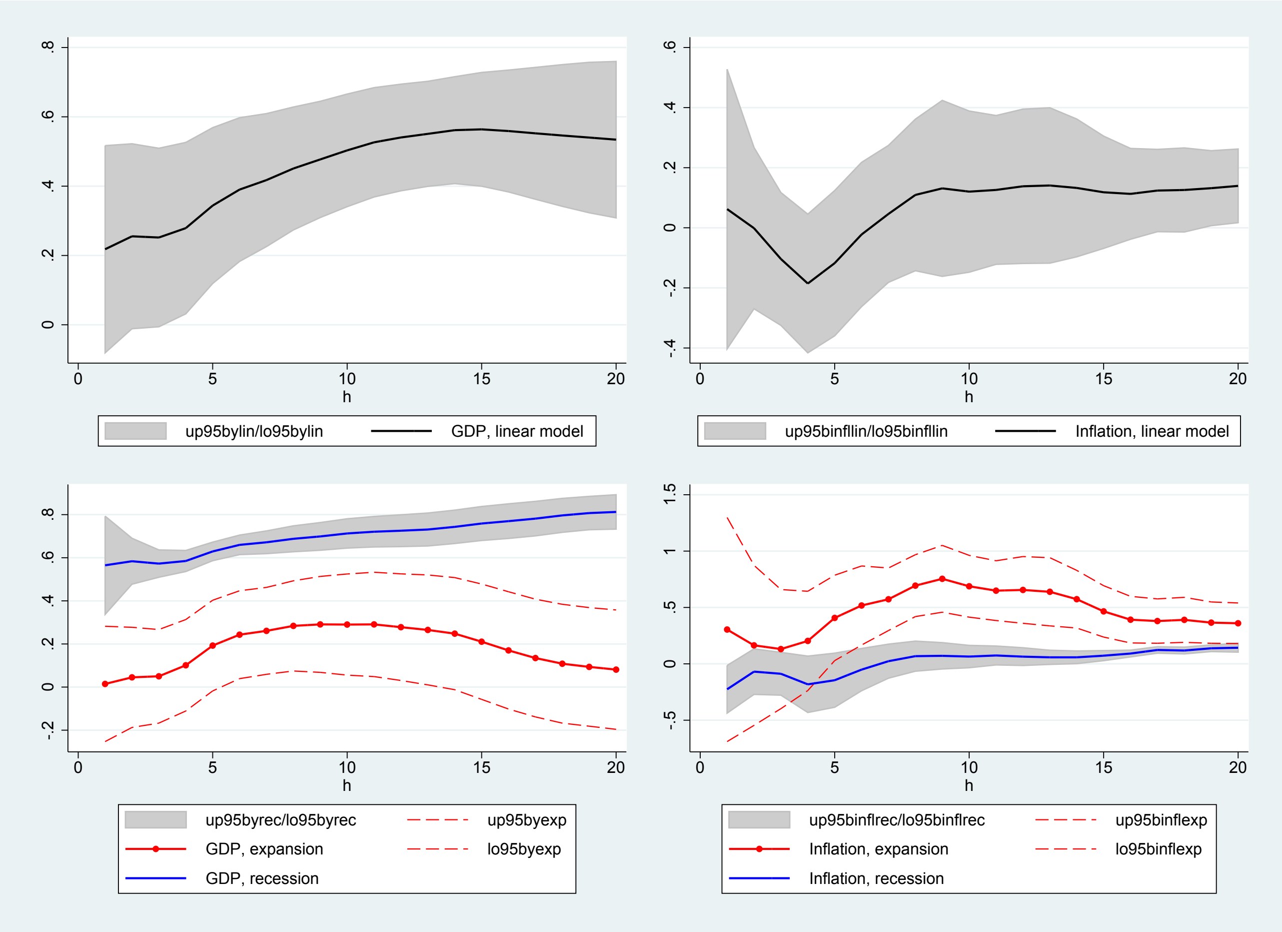
GDP

	Linear Model	Normal	Zero Lower Bound	P-Value
Military News Shock				
2 year Integral	0.66 (0.07)	0.63 (0.15)	0.77 (0.1)	0.43
4 year Integral	0.71 (0.04)	0.77 (0.38)	0.77 (0.06)	0.99
Blanchard Perotti Shock				
2 year Integral	0.39 (0.11)	0.1 (0.11)	0.64 (0.03)	0.000***
4 year Integral	0.47 (0.11)	0.12 (0.11)	0.71 (0.03)	0.000***
Combined				
2 year Integral	0.42 (0.098)	0.26 (0.1)	0.67 (0.03)	0.000***
4 year Integral	0.56 (0.08)	0.21 (0.14)	0.76 (0.04)	0.000***

Inflation

	Linear Model	Normal	Zero Lower Bound	P-Value
Military News Shock				
2 year Integral	0.31 (0.11)	1.07 (0.19)	0.41 (0.08)	0.003***
4 year Integral	0.14 (0.1)	0.98 (0.23)	0.11 (0.03)	0.000***
Blanchard Perotti Shock				
2 year Integral	-0.03 (0.1)	0.32 (0.11)	-0.04 (0.09)	0.007***
4 year Integral	0.06 (0.08)	0.27 (0.1)	0.04 (0.03)	0.03**
Combined				
2 year Integral	0.05 (0.11)	0.57 (0.14)	0.02 (0.08)	0.001***
4 year Integral	0.12 (0.1)	0.47 (0.12)	0.07 (0.02)	0.001***

Figure 2: Cumulative Multipliers for GDP and Inflation. Normal Times vs ZLB.



shows, the cumulative multiplier of GDP is significantly higher across all horizons. As for inflation, the cumulative multiplier is always lower, but this difference is significant only after 5 quarters.

Under some specifications, RZ find a cumulative multiplier effect on GDP at the ZLB that is higher than 1 and significantly different than in normal times. This is especially the case when they remove World War II from their sample. In Table 7 (reported in the appendix), I show the results associated with this specification. Interestingly, in those cases the cumulative effect on inflation is always lower at the ZLB. This difference is significant in roughly half of the specifications.

I also report other robustness exercises in Table 8. As RZ show, the instrument that combines the two shocks is the one with the best relevance near the ZLB. To save space, I focus on this one here and study a couple of deviations from the baseline specification. When the ZLB constraint is instead defined as the nominal rate on the T-Bill to be less than 0.5, I still find a that a higher cumulative GDP multiplier is associated with a lower cumulative multiplier on inflation. When I add controls for taxes and inflation (in the equation for GDP)

I find essentially the same results. The same goes when I control for the debt to GDP ratio.[16]

To sum up, an increase in government spending has a significantly positive cumulative effect on inflation overall. However, this effect is generally lower in situations when the cumulative multiplier effect on GDP is higher than normal, especially at the ZLB. This implies that the standard New Keynesian model cannot be considered a good laboratory to gauge the effects of government spending at the ZLB, as it has counterfactual predictions about the cumulative effects on inflation. To understand the subdued effects of government spending on inflation, I will develop a model with search and matching frictions on the labor market and a downward rigid nominal wage.

3 A New Keynesian model with search and matching frictions on the labor market

In this section, I augment the baseline New Keynesian model with a frictional labor market along the lines of Mortensen & Pissarides (1994). The model is close to the one developed in Ravenna & Walsh (2008). Time is discrete and one period equals one quarter. There are four types of agents in this economy : consumer / households, wholesale producers, retailers and a public authority that conducts both monetary and fiscal policy. I begin with the setup of the labor market.

3.1 The Labor Market : timing and flows

The size of the labor force is normalized to one. Employment decisions are taken by wholesale firms. Specifically, let N_{t-1} be the measure of employed people at the end of period $t-1$. At the begining of period t, a fraction s of employed workers is separated from wholesale firms. The workers that get separated immediately search for work during the period. The pool of job seekers is then

$$s_t = 1 - (1-s)N_{t-1}.$$

At the end of period t, the measure of unemployed people is given by $U_t = 1 - N_t$. To attract workers, the wholesale firms post a measure v_t of vacancies. Job seekers and vacancies are randomly matched according to the following constant returns to scale production function

$$m_t = m \cdot s_t^{\eta} v_t^{1-\eta},$$

where m governs the efficiency of the matching process. Let $\theta_t \equiv \frac{v_t}{s_t}$ denote the labor market tightness. Job seekers find work with probability $f(\theta_t) \equiv \frac{m_t}{s_t} = m\theta_t^{1-\eta}$ and firms fill a

[16]When I add linear and deterministic trends, the effect on GDP is significantly higher at very short horizons. At longer horizons, the difference is no longer statistically significant. The response for inflation is still significantly lower across the board. As there is no clear trend in inflation and GDP is divided by potential GDP, the rationale for adding deterministic trends is not clear.

vacancy at a rate $q(\theta_t) \equiv \frac{m_t}{v_t}$. To recruit, the firms pay a constant cost of r per vacancy posted. The law of motion for the measure of employed people in the wholesale sector is given by:

$$N_t = (1-s)N_{t-1} + v_t q_t. \tag{4}$$

The measure of employed people in the wholesale sector at t consists of the ones that were not separated and the new matches in the current period. Therefore, the aggregate recruiting expenses incurred by wholesale firms are given by:

$$\frac{r}{q(\theta_t)}[N_t - (1-s)N_{t-1}]. \tag{5}$$

The household's employment rate is given by the following law of motion:

$$N_t = (1-s)N_{t-1} + \big[1-(1-s)N_{t-1}\big] f(\theta_t). \tag{6}$$

The measure of employed people today consists of those that have not been exogenously separated plus those that have been separated and managed to find a job immediately after.

3.2 The Representative Household

The household is assumed to be large and solves the following maximization program:

$$\max_{C_t,B_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\prod_{j=0}^{t} \xi_j\right) \left\{\frac{C_t^{1-\sigma}}{1-\sigma} - \chi \frac{N_t^{1+\varphi}}{1+\varphi}\right\},$$

where φ indexes the degree of labor disutility[17] and ξ_t is a preference shock, which follows an $AR(1)$ process with persistence ρ_ξ. As in Merz (1995) and Galí (2010), there is perfect insurance. The budget constraint is:

$$P_tC_t + B_t = P_t(N_tW_t + b(1-N_t)) + R_{t-1}B_{t-1} + \mathcal{P}_t + \mathbb{1}\frac{\phi}{2}\left(\frac{\Pi_t}{\Pi} - 1\right)^2 N_t,$$

where P_t is the price level, C_t is a Dixit-Stiglitz aggregate of different varieties prduced by retailers, B_t are nominal one-period riskless bonds, R_t is the gross nominal interest rate, W_t is the real wage, b is the level of unemployment benefits and $\mathcal{P}_t$ are nominal profits distributed by retailer firms, net of lump sum taxes. Finally, $\Pi_t = \frac{P_t}{P_{t-1}}$ and if $\mathbb{1} = 1$, then the price adjustment cost for monopolistic firms is rebated lump-sum to the household. This is done to prevent this term to appear in the resource constraint of this economy, which can be the source of problems when the economy reaches the Zero Lower Bound (see Braun et al. (2012)). When $\mathbb{1} = 0$, the model nests the standard case. The Lagrangian for this program is

[17] With this assumption, the bargaining set will be smaller and when flexible, the real wage will fluctuate relatively less in a manner similar to Hagedorn & Manovskii (2008). This turns out to be very useful for the numerical algorithm to converge.

given by:

$$\mathcal{L}^H = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\prod_{j=0}^{t} \xi_j \right) \left\{ \frac{C_t^{1-\sigma}}{1-\sigma} - \chi \frac{N_t^{1+\varphi}}{1+\varphi} \right.$$
$$+\lambda_t \left[P_t(N_t W_t + b(1-N_t)) + R_{t-1}B_{t-1} + \mathcal{P}_t + \mathbb{1}\frac{\phi}{2}\left(\frac{\Pi_t}{\Pi} - 1\right)^2 N_t - P_t C_t - B_t \right]$$
$$\left. +V_{N,t}\left[(1-s)N_{t-1} + \left[1-(1-s)N_{t-1}\right] f(\theta_t) - N_t\right] \right\}.$$

The Lagrange multiplier on the budget constraint is the marginal utility of private consumption. The Lagrange multiplier on the law of motion of employment $V_{N,t}$ gives the value for the household of having one more employed worker. The first order conditions with respect to C_t and B_t is:

$$1 = R_t \mathbb{E}_t \left\{ \frac{\Lambda_{t,t+1}}{\Pi_{t+1}} \right\} \tag{7}$$

where $\Lambda_{t,t+1} = \beta \xi_{t+1} \left[\frac{C_{t+1}}{C_t} \right]^{-\sigma}$ is the stochastic discount factor which the household uses to discount future consumption. From this equation it is clear that a preference shock will have the effect to increase to returns on savings, prompting household members to consume less today.

3.3 The wholesale producer

There is a continuum of mass 1 of wholesale producers, indexed by i. They post vacancies to attract new workers, who become immediately productive. They produce output according to the following constant returns to scale production function:

$$Y_t^w(i) = N_t(i),$$

where the w superscript stands for wholesale. The output of the wholesale firm is sold to the retailers in a competitive market[18] at a price P_t^w—I drop the index i for the price since the firms are atomistic and take the price as given. The same goes for the real wage. The profit of the wholesale firm is then:

$$\frac{P_t^w}{P_t} N_t(i) - \frac{W_t}{P_t} N_t(i) - r \cdot v_t(i), \tag{8}$$

where P_t is the welfare relevant price index of the final good and W_t is the nominal wage. The wholesale firm maximizes its profits by choosing the number of people it wants to employ

[18] As in Ravenna & Walsh (2008), I make this assumption to keep the bargaining problem for wages tractable. Indeed, when one assumes that the firm sells its output in a monopolistic competitive environment, the marginal worker reduces the marginal revenue product. In this case, the marginal worker has a lower wage than the average wage, which gives incentives for firms to overemploy. This can also be the case when the production function exhibits decreasing returns to scale (see Cahuc et al. (2008)). With perfect competition and constant returns to scale, all workers are the same so that the marginal wage is equal to the average wage.

and the number of vacancies it has to post to do so,[19] subject to the constraint (4). The Lagrangian of this problem then is:

$$\mathcal{L}^F = \mathbb{E}_0 \sum_{t=0}^{\infty} \left(\prod_{j=0}^{t} \xi_j \right) \beta^t C_t^{-\sigma} \Bigg\{ \left(\frac{P_t^w - W_t}{P_t} \right) N_t(i) - r \cdot v_t(i) \\ - V_{J,t}(i) \left[N_t(i) - (1-s) N_{t-1}(i) - q(\theta_t) v_t \right] \Bigg\},$$

where I have substituted for the production function. Combining the first order conditions with respect to the measure of employment and vacancies, I get the following expression:

$$\frac{P_t^w}{P_t} = \frac{W_t}{P_t} + \frac{r}{q(\theta_t)} - (1-s) E_t \frac{r \cdot \Lambda_{t,t+1}}{q(\theta_{t+1})}. \tag{9}$$

In equilibrium, the marginal revenue product by one more worker should be equal to the cost incurred by the firm from having this additional worker. This includes the recruitment cost (since a vacancy is filled at a rate $q(\theta_t)$, the firm has to post $\frac{r}{q(\theta_t)}$ of them to attract one worker) and the real wage payment. To this, we must add the benefit (the negative cost) of having one less worker to recruit tomorrow. Since all the wholesale producers are identical, they will all hire the same measure of workers and produce the same quantity of output

$$Y_t^w(i) \equiv Y_t^w \quad \forall i$$

which they sell at price P_t^w to the retailers.

3.4 Wage setting

Once the government spending and preference shocks are realized, job seekers and firms meet and bargain over the real wage, which cannot go below a floor level $\underline{W}$ that is taken as exogenous by both participants.[20] Let $\tilde{V}_{N,t}$ and $V_{J,t}$ denote, respectively, the value of employment for the household and the value of a job for a firm. The first one is equal to the Lagrangian multiplier in front of the employment transition equation in the consumer program, scaled by the marginal utility of private consumption $C_t^{-\sigma}$. Likewise, $V_{J,t}$ is equal to the Lagrangian multiplier in front of the employment transition equation in the firm program. The real wage (denoted by $\mathcal{W}$) is the one that maximizes the log of the joint surplus of the representative firm and household, taking into account that the agreed upon real wage outcome is bounded from below, *i.e*

$$\mathcal{W}_t = \arg \max_{\mathcal{W} \geq \underline{\mathcal{W}}} \log \left(\tilde{V}_{N,t}^{1-\mu} V_{J,t}^{\mu} \right),$$

[19] In practice, we can reduce the problem of directly choosing the number of people to employ, the measure of vacancies necessary to achieve this level given by (5). However, it is useful to state the maximization problem with respect to both $N_t(i)$ and $v_t(i)$ to derive the value for the firm of an additional worker, which will be used later to derive the bargained wage.

[20] The wage of incumbents and new workers will be the same in this framework, since all the workers are identical.

where μ is the bargaining power of the firm. In this setup, the presence of downward wage rigidity will imply that both participants anticipate that the constraint might be binding in the next period. As a consequence, the expression for the bargained wage will be different from the standard flexible wage and is given by:

$$\mathcal{W}_t = \mathcal{W}_t^{\text{flex}} + \lambda_t^w \tilde{V}_{N,t} \frac{r}{q(\theta_t)} + (1-s)(1-\mu)\mathbb{E}_t D(\lambda_{t+1}^w, \theta_{t+1}) \tag{10}$$

$$D(\lambda_{t+1}^w, \theta_{t+1}) \equiv \Lambda_{t,t+1}(1 - f(\theta_{t+1}))\frac{r}{q_{t+1}}\lambda_{t+1}^w \frac{1}{1 - \frac{\mu}{r}q_{t+1}} \tag{11}$$

$$\mathcal{W}_t^{\text{flex}} = \mu \left(b + \chi \frac{N_t^{\varphi}}{C_t^{-\sigma}} \right) + (1-\mu)\left(\frac{P_t^w}{P_t} + (1-s)\mathbb{E}_t \Lambda_{t,t+1} r \cdot \theta_{t+1} \right), \tag{12}$$

where b is the replacement rate of unemployment benefits and $\lambda_{t+1}^w \geq 0$ is the multiplier on the downward rigidity constraint, which further implies that

$$\text{either } \mathcal{W}_t > \underline{\mathcal{W}}_t \ \& \ \lambda_t^w = 0 \quad \text{or} \quad \mathcal{W}_t = \underline{\mathcal{W}}_t \ \& \ \lambda_t^w > 0.$$

Note that from equation (10), the negotiated wage nests the usual flexible solution if $\lambda_t^w = \lambda_{t+1}^w = 0$. This happens if the rigidity constraint is so loose (for instance, $\underline{\mathcal{W}}_t = 0$) that it is never binding in equilibrium. On the other hand, if the constraint is occasionaly binding, then the two wages will be different. Even if $\lambda_t^w = 0$ so that the constraint is not binding today, the mere possibility that it might be binding tomorrow creates a wedge between the flexible and rigid wage.[21] Following Schmitt-Grohé & Uribe (2012b), I allow the nominal wage to be potentially downward rigid.[22] Formally, nominal wages are required to satisfy the following condition :

$$W_t \geq \gamma W_{t-1}, \quad \gamma \geq 0.$$

Straightforward algebraic manipulations imply that real wages are downward rigid as a consequence:

$$\mathcal{W}_t \geq \gamma \frac{\mathcal{W}_{t-1}}{\Pi_t}, \quad \gamma \geq 0. \tag{13}$$

Following Hall (2005), I verify that the realized real wage always lies in the bargaining set for this model. When $\gamma = 0$, the model has a flexible real wage.

3.5 The retailers

There is a large number of retailers, indexed by j. They buy intermediate goods from the wholesale producers, which they use to transform into final goods with a one to one technology:

$$Y_t(j) = N_t.$$

[21] From equation (11), the difference can be positive or negative. This effect is not quantitatively strong however : for all the ξ_t grid points on which the model is solved, the maximum difference between the two wages is equal to 0.2% of the steady state wage (which is the same in both settings).

[22] The prevalence of downward rigid nominal wages has been documented by many studies. See Dickens et al. (2007) for a survey of this literature. More recent contributions include Barattieri et al. (2014) and Schmitt-Grohé & Uribe (2015).

They each sell a different variety of the final good. They know that they face a demand for their variety given by:

$$Y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon} Y_t,$$

where ϵ is the elasticity of substitution across the different varieties, $P_t(j)$ is the price of the variety produced by retailer j and Y_t is a CES aggregate of all the varieties. The retailer pays a quadratic cost to adjust his price as in Rotemberg (1982). He buys Y_t^w of intermediate goods at a price P_t^w. Therefore, the *real* marginal cost of producing one more unit of the final good is equal to $MC_t = \frac{P_t^w}{P_t}$. Anticipating the results, I assume a symmetric equilibrium for the retailers : each one will produce the same amount using the same quantity of intermediate good. Therefore, his real profit is given by:

$$\frac{\mathcal{P}_t(j)}{P_t} = \left[\left(\frac{P_t(j)}{P_t}\right)^{1-\epsilon} - \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon} MC_t\right] Y_t - \frac{\phi}{2}\left(\frac{P_t(j)}{P_t} - 1\right)^2 Y_t \tag{14}$$

Since they are owned by the households, the retailers' problem is to choose a price that maximizes the present discount value of real profits given by:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \left(\prod_{j=0}^{t} \xi_j\right) \beta^t C_t^{-\sigma} \frac{\mathcal{P}_t(j)}{P_t}.$$

The first order condition with respect to P_t then gives the standard New Keynesian Phillips Curve:

$$\phi \frac{\Pi_t}{\Pi}\left(\frac{\Pi_t}{\Pi} - 1\right) = 1 - \epsilon + \epsilon MC_t + \phi \mathbb{E}_t \left\{\Lambda_{t,t+1} \frac{Y_{t+1}}{Y_t} \frac{\Pi_{t+1}}{\Pi}\left(\frac{\Pi_{t+1}}{\Pi} - 1\right)\right\}, \tag{15}$$

where Π is the steady state inflation rate.

3.6 Fiscal and Monetary Policy

The government finances an exogenous stream of expenses G_t plus unemployment benefits by levying non-distortionary, lump-sum taxes. Government expenses follow an $AR(1)$ process with persistence ρ_g. In contrast to Michaillat (2014), government spending does not take the form of public employees. While public employees do represent a sizable share of government spending in the data, I am interested here—as is most of the literature on the effects of government spending —in the effects on aggregate output of the purchase of goods by the government. In fact, public employment did not represent a large share of the American Recovery and Reinvestment Act of 2009, if anything at all.[23] The budget constraint of the government then is:

$$T_t + \frac{B_t}{P_t} = G_t + b(1 - N_t) + \frac{R_{t-1}}{P_t} B_{t-1}$$

[23] With spending reversals on the state level, one can even argue that the net effect of ARRA on public jobs might be negative.

The Monetary Authority sets the gross nominal interest rate according to:

$$R_t = \max\left\{1, \frac{\Pi}{\beta}\left(\frac{\Pi_t}{\Pi}\right)^{\phi_\pi}\right\}. \tag{16}$$

For simplicity, the nominal interest rate does not react to its past value.

3.7 Equilibrium

Substituting the definition of real profits in the household's budget constraint and combining the result with the government budget constraint, one gets the resource constraint of this economy:

$$Y_t\left[1-(1-\mathbb{1})\frac{\phi}{2}\left(\frac{\Pi_t}{\Pi}-1\right)^2\right] = C_t + G_t + \frac{r}{q(\theta_t)}[N_t-(1-s)N_{t-1}] - b(1-N_t). \tag{17}$$

3.8 Model Solution and Calibration

The model requires a large shock on the discount factor to drive the economy to the ZLB. Therefore, I do not rely on log-linear approximations around a deterministic steady state, as is usually done. Being based on a Taylor expansion of the first order conditions, these approximations are only valid in a small neighborhood of the steady state. In fact, it has been shown that the usual discount factor shock takes the economy too far from the steady state for those approximations to remain valid (see Braun et al. (2012)). Christiano & Fisher (2000) argue that a special case of projection methods, the Parameterized Expectations Algorithm (PEA) is the most efficient one to approximate models with occasionally binding constraints. Accordingly, I solve the model globally using this algorithm, as in Albertini et al. (2014).

This algorithm consists in approximating the expectations functions of the model by a simple polynomial function of the state variables. Beginning with a first guess of the coefficients relating the expectations functions to the polynomials, I can compute the policy rules relating the endogenous variables to the state variables. Importantly, since there are two occasionally binding constraints, I estimate four different policy rules, *i.e* one for each possible case. As a consequence, this algorithm is very well suited to take into account the eventual kinks in the policy rules. Using these along with the transition equations of the state variables, I can compute the expectations using a Gauss-Hermite quadrature. I then regress those expectations on the state variables to update the value of the coefficients in front of the polynomials. I iterate on these coefficients until the difference at successive iterations is small enough. I explain the algorithm in greater detail in the Appendix C.

I now move to the calibration of the model. The model is calibrated at quarterly frequency. The elasticity of substitution across goods is equal to $\epsilon = 6$, which yields a markup of 20 %. I set $\beta = 0.994$ to get an annual real interest rate of 2.5% as in Fernández-Villaverde et al. (2015). I set $\sigma = 1$ as in Christiano et al. (2011). I choose the price rigidity parameter so that in the linear New Keynesian Phillips Curve the elasticity of inflation to the real marginal cost is consistent with an average price duration of four quarters. This yields $\phi = 60$. Now moving to the labor market, I set $\eta = 0.5$ for the elasticity of the matching function with respect to unemployment (see Pissarides & Petrongolo (2001)). The exogenous separation rate is set to $s = 0.11$ as in Krause et al. (2008). The labor disutility parameter is set to $\varphi = 1$ as in Fernández-Villaverde et al. (2015). Following Michaillat (2014), steady state unemployment is set to 6.4%, which yields an employment level of $N = 0.936$. The matching efficiency parameter is set so that, at steady state, $q(\theta) = 0.7$ (see Ravenna & Walsh (2008)). This yields $m = 0.657$. I set a standard value of $b = 0.4$ for the replacement rate. The bargaining power of the household is set to $\mu = 0.5$ so that the Hosios (1990) condition holds. Finally, $\chi = 0.506$ is set so as to balance the steady state wage equation. I set the vacancy posting cost parameter so that total recruitment costs $r \cdot v$ amount to 1% of steady state output as in Christiano et al. (2013). This ensures that the presence of recruitment costs in the resource constraint will not matter much quantitatively. The share of government spending with respect to output is set to the conventional value of 20%. To prevent the adjustment costs to play a big role in the resource constraint, I assume $\mathbb{1} = 1$ in my baseline calibration.[24] The calibrated parameters are summarized in Table 9 (in the Appendix).

The more volatile and persistent the shocks are, the harder it is to get an accurate solution for the model. Based on these considerations, I set $\sigma_g = \sigma_\xi = 0.002$. As in Christiano et al. (2011) I set $\rho_g = \rho_\xi = 0.8$. Finally, following Schmitt-Grohé & Uribe (2012a) and Schmitt-Grohé & Uribe (2012b) I set $\gamma = 0.99$ in the model with downward nominal wage rigidity. For the model with flexible wage, I set $\gamma = 0$.

3.9 Price and quantities adjustment in expansions/recessions

In his paper, Michaillat (2014) argues that when the economy is in a recession, labor market tightness is low and reacts less when the government increases public employment. As a consequence, the crowding out effect on private labor demand is less than in an expansion, when labor market tightness is high and reacts a lot more. Since in his framework the real wage is entirely exogenous and given by aggregate productivity, the latter is not amenable to study the implications inflation dynamics.

In the present setup, the real wage can (and will) react differently in expansions and recessions. Since the real wage is an important component of real marginal cost and firms set prices as a markup over the latter, inflation will react differently over the cycle. Given that arguably inflation plays a large role at the Zero Lower Bound, this is a desirable feature. To study how prices and quantities adjust respectively when the labor market is depressed or booming, I plot the ergodic distribution[25] of unemployment, inflation and the real wage

[24] It also turns out that the model is easier to solve with this assumption.

[25] I also compute the residuals of the Euler equations for the whole simulation period. For a simulation length of 1 million periods, all three residuals are of the order of 10^{-6} on average. Therefore, despite the

with respect to labor market tightness in Figure 3.

I first focus on the model with a flexible real wage, *i.e* the left panels. Generally, a low tightness corresponds to parts of the state space where demand for final goods is low, therefore labor demand is low. This explains the negative relationship between unemployment and labor market tightness. Additionally, the later is more convex than linear as employment prospects gradually worsen as labor market tightness declines. This feature comes from the matching frictions embedded in the model. Indeed, from equation 6 one can see that given N_{t-1}, $1 - N_t$ is a convex function of θ_t. When labor market tightness is low, so is $f(\theta_t)$ and it is much harder for job seekers to actually find a job. On the firm side, the presence of a large pool of job seekers means that it is easier to recruit them and $q(\theta_t)$ is high. It follows that variations in labor demand will trigger an adjustment along the employment margin when labor market tightness is lower than its steady state value.

As quantities adjust relatively quickly to variations in labor demand during a recession, prices adjust relatively less. Indeed, it is apparent from the inflation and real wage distributions that they become less sensitive to labor market conditions when the latter are dire, *i.e* labor market tightness is low.

The same goes for the model with downward wage rigidity, with an additional twist. On the one hand, this rigidity means that the real wage will be too high in a recession, depressing profits and hiring activities of firms. In a RBC model with a frictional labor market, this would make the recession worse. Here, the downward rigidity of wages also means that marginal costs and inflation will fall by less in a deep recession. As a consequence, this will mitigate the vicious feedback loop that turns deflation into a higher real interest rate at the ZLB.[26] Those two effects are of a similar magnitude, so that the distribution of employment outcomes are not very different with and without downward wage rigidity.

To finish with this subsection, the absence of a deflationary spiral makes it an appealing framework to work with, since we did not really observe a large fall in inflation during the current Great Recession. This has been dubbed the "missing deflation" puzzle.[27] For this reason and the fact that the empirical findings described earlier pointed towards the low reaction of inflation in (deep) recession times, I will mainly focus on the model that features such frictions. In particular, I will analyze (i) the type of recession this model generates and (ii) whether fiscal policy has asymmetric effects over the cycle.[28] It is however useful to briefly look first at the model with flexible wages to understand the specific contribution of search and matching frictions on the labor market.

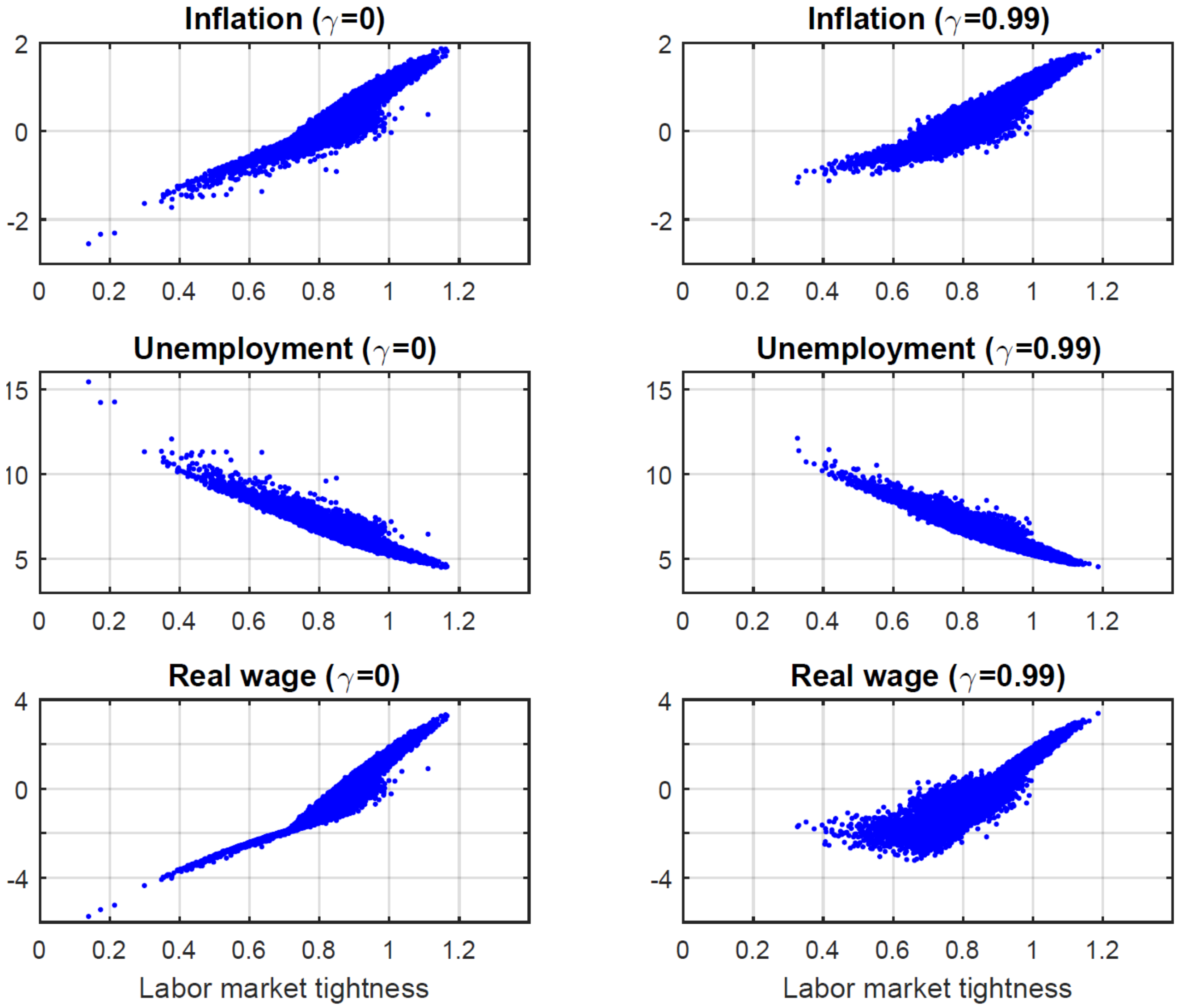
presence of multiple kinks the algorithm is able to represent rather accurately the dynamics of the model.

[26] I thank Tommaso Monacelli for suggesting this idea.

[27] See Gordon (2013), Del-Negro et al. (2014) and Coibion & Gorodnichenko (2015), among others.

[28] I should say upfront that the goal is not to match perfectly the impulse responses estimated earlier on U.S. data. To do that, I would need to add additional ingredients such as consumption habits, private capital with adjustment costs *etc.* These would add endogenous state variables and thus make the model much harder to solve globally.

Figure 3: Inflation, Employment and the Real Wage in Good/Bad Times, based on one million simulated data points.



Notes: Inflation is reported in annualized terms. Unemployment is in percent of the labor force. The real wage is in percent deviation from its steady state value.

4 Government Spending Effects in Recessions vs Expansions

In the model I have developed, fluctuations are driven by two aggregate demand shocks : a preference and a government spending shock. In this section, I will use the preference shock to create a recession or an expansion. Once the economy is in one of these two states, I will implement a government spending shock and gauge the potentially different effects in these two scenarios. To make sure that the effects can be clearly discernible on the figures, I calibrate the size of the government spending shock so that it amounts to 1% of steady state government spending.

4.1 A First Quantitative Exercise with Flexible Wages

In this subsection, I assume $\gamma = 0$. This will allow me to (i) highlight the role of the non-linear algorithm in generating asymmetric responses in recessions vs expansions and (ii) motivate the inclusion of a downward rigid nominal wage. To generate a recession, I take the highest level of the shock ξ_t, conditional on the fact that the ZLB is not binding. For the expansions scenario, I take the opposite of this shock.

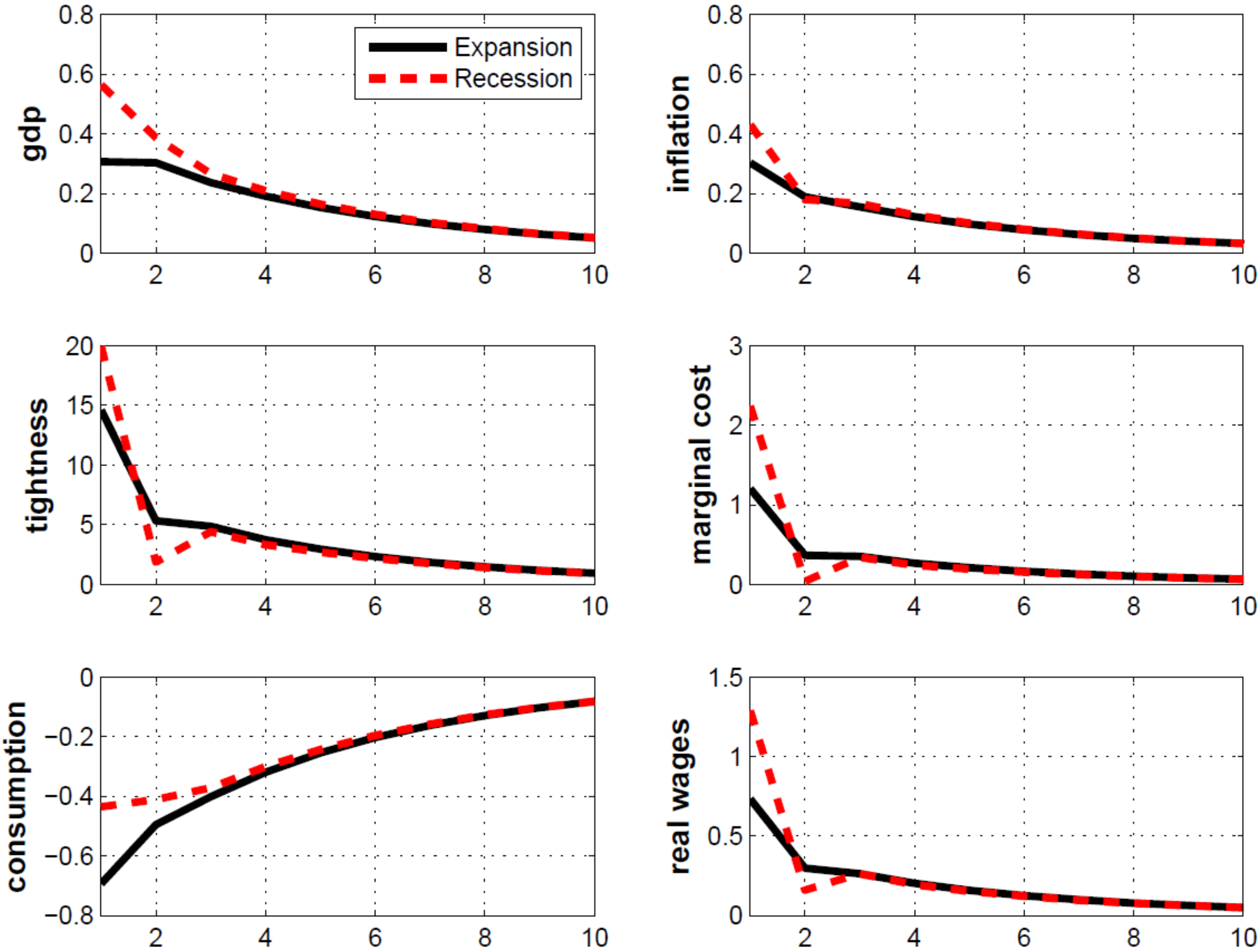
To gauge the effects of government spending in recessions vs expansions, I proceed as follows. For each scenario, I plot the difference between the simulated path of the economy with and without the government spending shock, scaled by the initial variation in government spending. As such, the responses depicted in Figure 4 can be interpreted as dynamic multipliers. It is clear that this model, when solved globally, can generate a larger effect of government spending in a recession. A large pool of unemployed people means that a vacancy is filled more easily.[29] As a consequence, employment and GDP react more after a government spending shock in a recession. The underlying mechanism is similar to the one presented in Michaillat (2014). Here, I show that this mechanism holds even without assuming an exogenous rigid wage. The fact that employment is comparatively higher in a recession (conditional on the government spending shock) implies that consumption decreases by less in a recession. As a result, contrary to the empirical evidence presented before, inflation reacts by more in a recession.

Because of its simplicity, the model is not able to produce a hump-shaped response for the main variables as in the empirical responses shown before. Indeed, with a separation rate of $s = 0.11$, unemployment dynamics are not sufficient to yield such a result.[30] Consequently, as in the standard New Keynesian model, the maximum response is reached on impact and the economy goes back monotonically to its steady state. This caveat notwith-

[29]Note that the government spending shock has a large effect on labor market tightness, whether in expansion or recession. This is due to the fact that households experience disutility from labor market activities. Similar to the analysis in Ljungqvist & Sargent (2015), the presence of disutility diminishes the size of the fundamental surplus that can be allocated to vacancy creation. As such, an increase in government spending will generate a comparatively large increase in vacancies and labor market tightness.

[30]With a lower separation rate, the model would exhibit a higher degree of persistence, but the algorithm fails to converge for such parameter values.

Figure 4: Impulse Responses to a Government Spending Shock in Expansions/Recessions with flexible wage.



Notes: The black line represents the difference between the path of GDP/inflation with i) only a positive preference shock and ii) a preference and government spending shock. This difference is then scaled by the initial increase in government spending, so that the response is the multiplier effect of government spending. The red dashed line represents the same but with a negative preference shock.

standing, one can see from Figure 4 that employment —and thus, GDP —reacts more in a recession because it is easier to meet the additional demand coming from higher government purchases.

Consider now what happens with a larger shock that sends the economy at the ZLB.[31] In this setup nothing prevents the real wage to adjust downward so that after a negative preference shock sends the economy at the ZLB, a deflationary spiral breaks out. Likewise, when government spending increases while the economy is at the ZLB, the impact multiplier effect on (annual) inflation is higher than 3, *i.e* much higher than what the data says. Both of these features can be seen in Figures 10 and 11 (in the Appendix). I summarize the results obtained for the model with flexible wages in Table 3. To facilitate the comparison with the empirical section, I compute again 2 and 4-year cumulative multipliers. By this metric, the model again predicts that inflation should react more in a recession, and *a fortriori* when the ZLB becomes a binding constraint. In the next subsection, I show how the introduction of a downward rigid wage can mitigate these shortcomings.

Table 3: Cumulative GDP/Inflation Multipliers Across States in the Model with Flexible Wages

	Expansion	Recession	ZLB
GDP			
2 year Integral	0.36	0.48	0.84
4 year Integral	0.36	0.47	0.79
Inflation			
2 year Integral	1	1.16	1.72
4 year Integral	1	1.14	1.63

4.2 Simulations with a Downward Rigid Wage

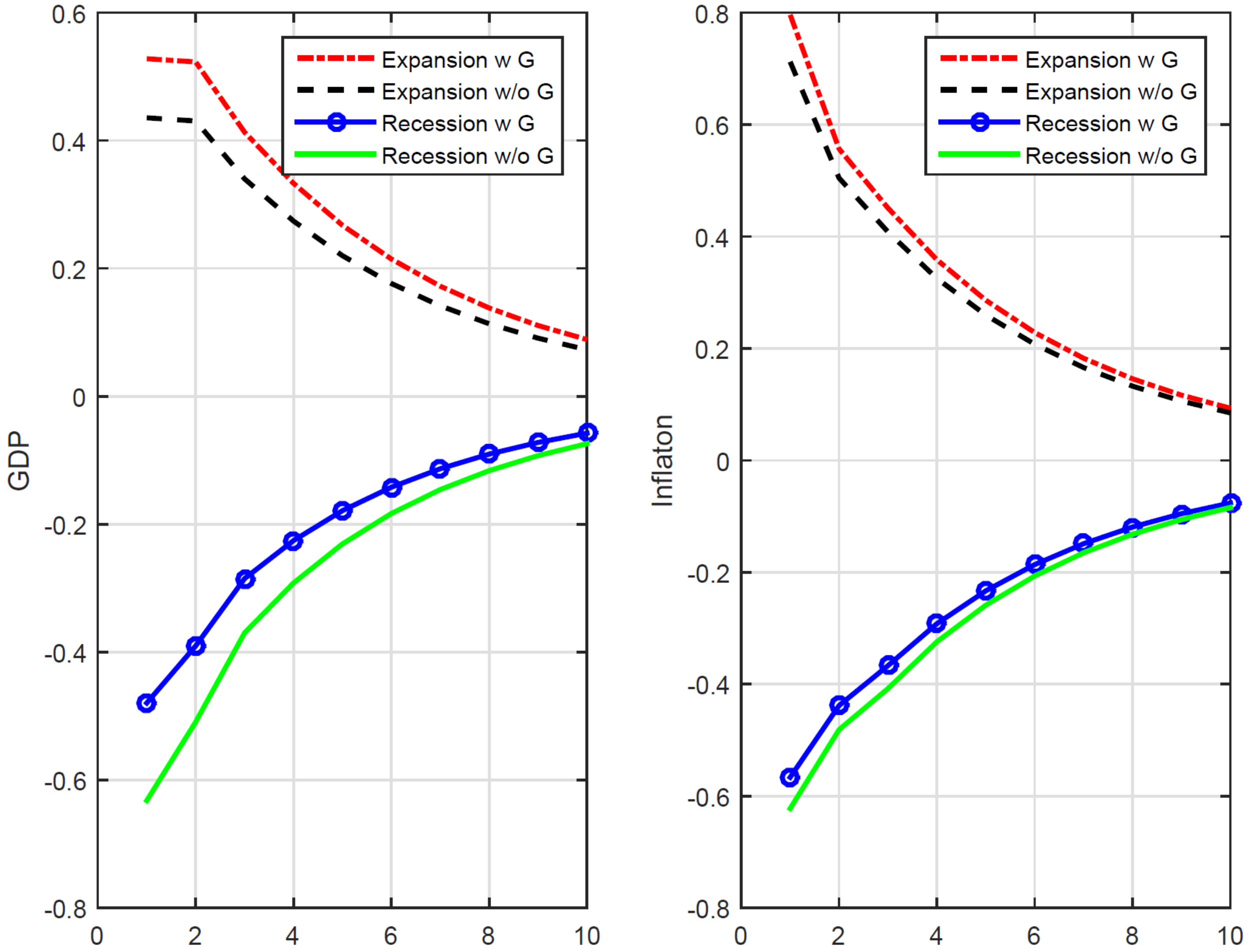
I first analyze a standard recession when only the DNWR constraint is binding.[32] In Figure 5, I plot the results of the first experiment. I first concentrate on the responses of the economy without an increase in government spending.

Regarding GDP, the recession is larger in magnitude than the expansion. This reflects the fact that adjustment operates more through quantities in recessions. Since there is a fall in inflation in a recession, the real wage will be higher than the desired real wage and firms will cut down on vacancy posting. This exacerbates the fall in employment in a recession.

[31] I calibrate the size of the shock so that the decline in GDP is the same as the one I will have in the model with downward wage rigidity. This requires a somewhat lower shock than in the model with DNWR.

[32] For my baseline calibration, I need a bigger shock to make the ZLB constraint binding than for the DNWR one (see the policy rules in Figure 12 in the appendix). This means that I can disentangle the effects of the two constraints.

Figure 5: Recession/Expansions with and without Government Spending Shocks with downward rigid wage



Note: Both variables are expressed as percentage deviations from their steady state value.

In an expansion, an increase in inflation will play an opposite role so that firm's profits are higher and they post more vacancies.

The flip side of this feature is that inflation reacts more in an expansion than in a recession. In the latter scenario, the high level of the real wage prevents marginal costs from falling too much, which dampens the fall in inflation. In an expansion, this effect is altogether absent. On this front, the predictions of the model line up well with the empirical evidence showing that recessions are usually more severe than booms are expansionary.[33] The muted decline in inflation is also a desirable feature in light of the recent debate about the "missing deflation" puzzle.

I now turn to the effects of government spending in an expansion. This induces a higher demand for final goods, which is met by higher employment through increased vacancy posting. The increase in vacancies is however limited as a high labor market tightness makes it harder to recruit workers. In addition, the real wage increases and puts upward pressure on the real marginal cost. This generates inflation and calls for the Central Bank to increase its nominal rate. The resulting increase in the real interest rate depresses private consumption, which decreases labor demand. In the end, the multiplier effect is lower than 1 and rather small. More precisely, taking the difference on impact between an expansion with and without government spending, scaling it to the initial increase in government spending gives a GDP multiplier of 0.31 on impact. The reason why it is much smaller than the one obtained with the simple New Keynesian model is because employment is now a state variable that only adjusts partially in the short run.

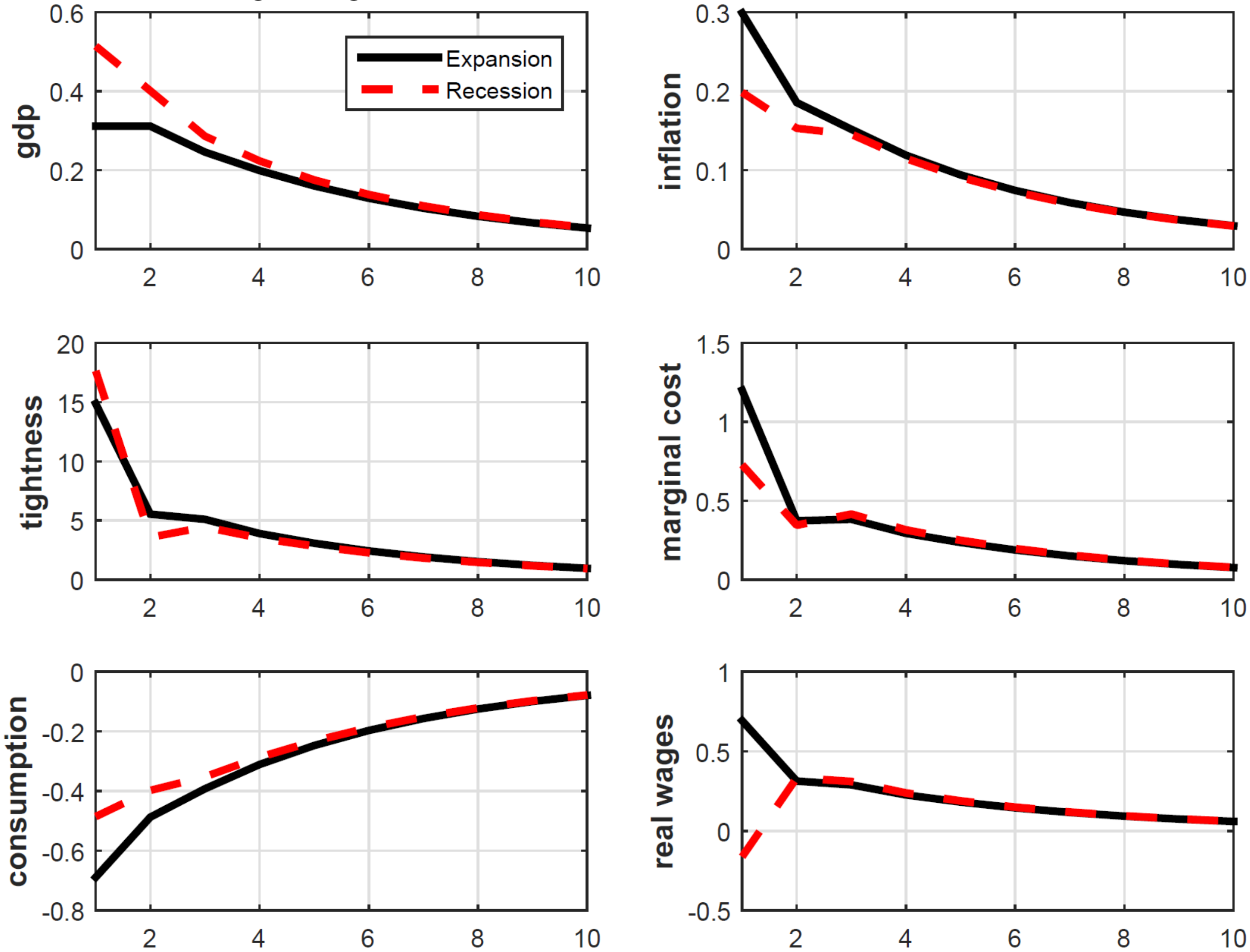
With this in mind, I now analyze the effects of government spending in a typical recession. One can see that increasing government spending has a higher multiplier effect in a recession. Computing the latter yields a value of 0.51 on impact, *i.e* 65% higher than in the expansion scenario. To make sure that the difference between the two does not depend too much on the fact that the recession is comparatively larger than the expansion, I augment the size of the shock that generates an expansion so that it is of the same magnitude.[34] In this experiment, the difference between the multipliers is now of 67% in favor of the multiplier in a recession. Basically, as the expansion is stronger, the economy is over-heating and the adjustment occurs even more through prices rather than quantities.

The interpretation goes as follows. The same mechanisms that have been described for the model with flexible wage apply here. Additionally, since the DNWR constraint is binding on impact, more inflation leads to a lower real wage. In equilibrium, this dampens the response of inflation. As a result, while the multiplier effect on GDP is higher in a recession, the effect on inflation is actually *lower*. This can be seen clearly in Figure 6, where I again plot the difference between the path with and without an increase in government spending for each scenario.

[33] See for example the evidence reported in McKay & Reis (2008) and Abbritti & Fahr (2013).

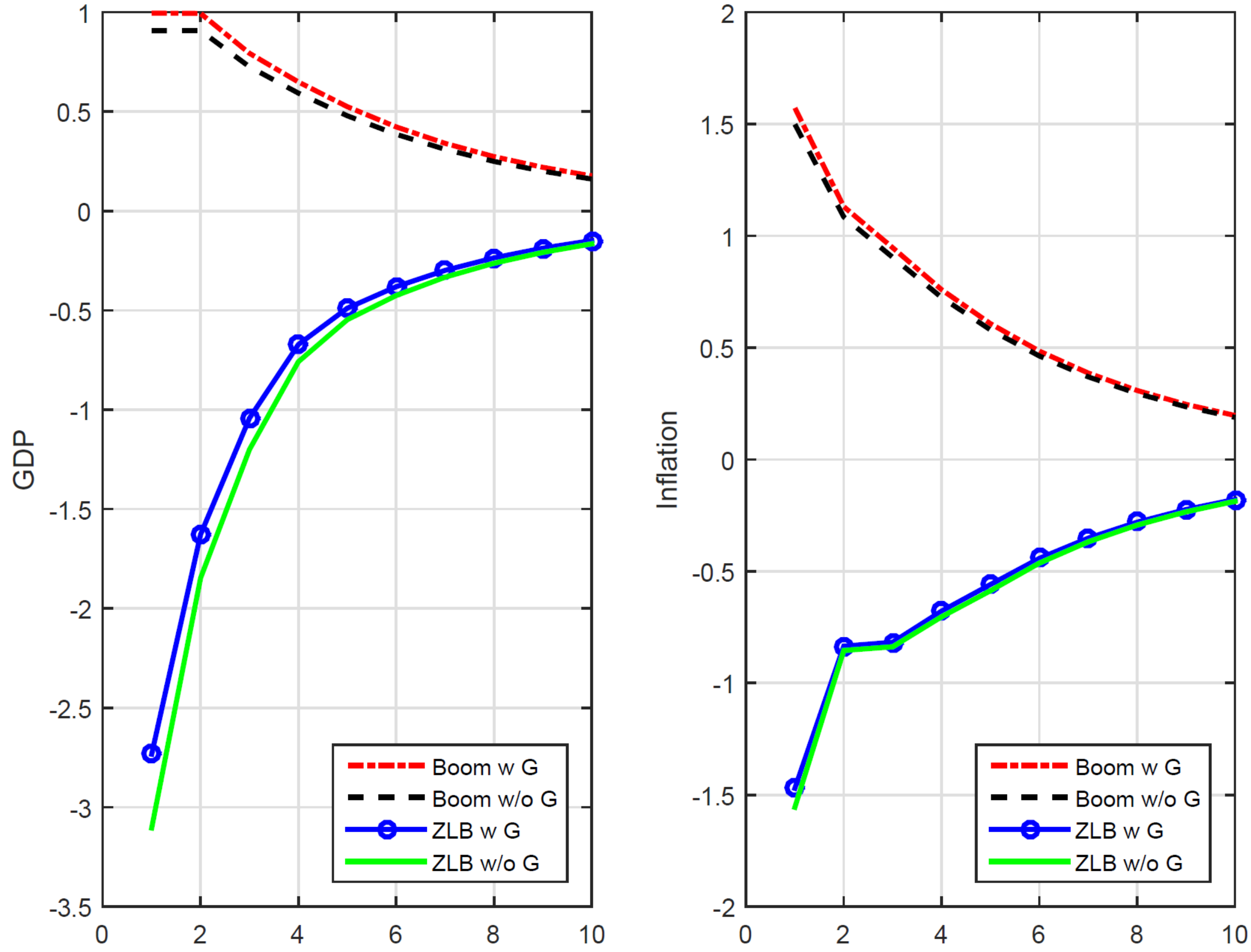
[34] This requires a shock that is 18% higher.

Figure 6: Impulse Responses to a Government Spending Shock in Expansions/Recessions with downward rigid wage.



Notes: The black line represents the difference between the path of GDP/inflation with i) only a positive preference shock and ii) a preference and government spending shock. This difference is then scaled by the initial increase in government spending, so that the response is the multiplier effect of government spending. The red dashed line represents the same but with a negative preference shock.

Figure 7: ZLB/Boom with and without Government Spending Shocks with downward rigid wage



Note: Both variables are expressed as percentage deviations from their steady state value.

4.3 A Liquidity Trap Scenario

I now study the effects of government spending when the preference shock is large enough to send the economy in a liquidity trap. In this case, both the DNWR and ZLB constraints are going to be binding. For the sake of comparison, I still plot the simulations during the boom period in Figure 7.

The preference shock that generates a deep recession sends the economy at the ZLB for 3 periods. I verify that the increase in government spending does not affect the duration of the liquidity trap so that the multiplier that I compute is not biased upwards. Without the increase in government spending, GDP troughs at -3.1%.[35] With the increase in government spending, the trough is at -2.85%. Consistent with a large body of literature, if I

[35] I could potentially engineer a deeper recession, but then labor market tightness becomes negative and approximations error will increase. For these reasons, I stick with this calibration.

compute the difference between those two numbers and scale it by the increase in government spending, I obtain a multiplier larger than unity.[36] In this case, I obtain 1.27.

When the economy reaches the ZLB, the recession is a lot worse than the associated expansion. The recession is characterized by a rather small deflation that puts upwards pressure on the real wage, thereby limiting the deflationary spiral. Indeed, note that the reaction of inflation is rather symmetric between the boom and ZLB scenarios.

The fact that government spending has more effects in a liquidity trap is nothing new. But usually this rests on an inflationary spiral that is not found in the data. In this model however, because wages are downward rigid and firms can recruit more easily in a recession, inflation reacts *less* on average with the increase in government spending compared to the expansion case.[37] As a consequence, the evidence that a fiscal package did not generate a burst of inflation does not necessarily constitute evidence for its lack of stimulative properties. This can be seen clearly in Figure 8.

I again summarize the implications of this model for the cumulative multiplier effects in Table 4. Contrary to what can be found in Table 3 (for the model with flexible wage), now we see that the model predicts lower cumulative multipliers on inflation both in recessions and ZLB episodes. In this sense, the model with rigid wages is able to reproduce the empirical findings reported earlier.

Table 4: Cumulative GDP/Inflation Multipliers Across States in the Model with Downward Rigid Wages

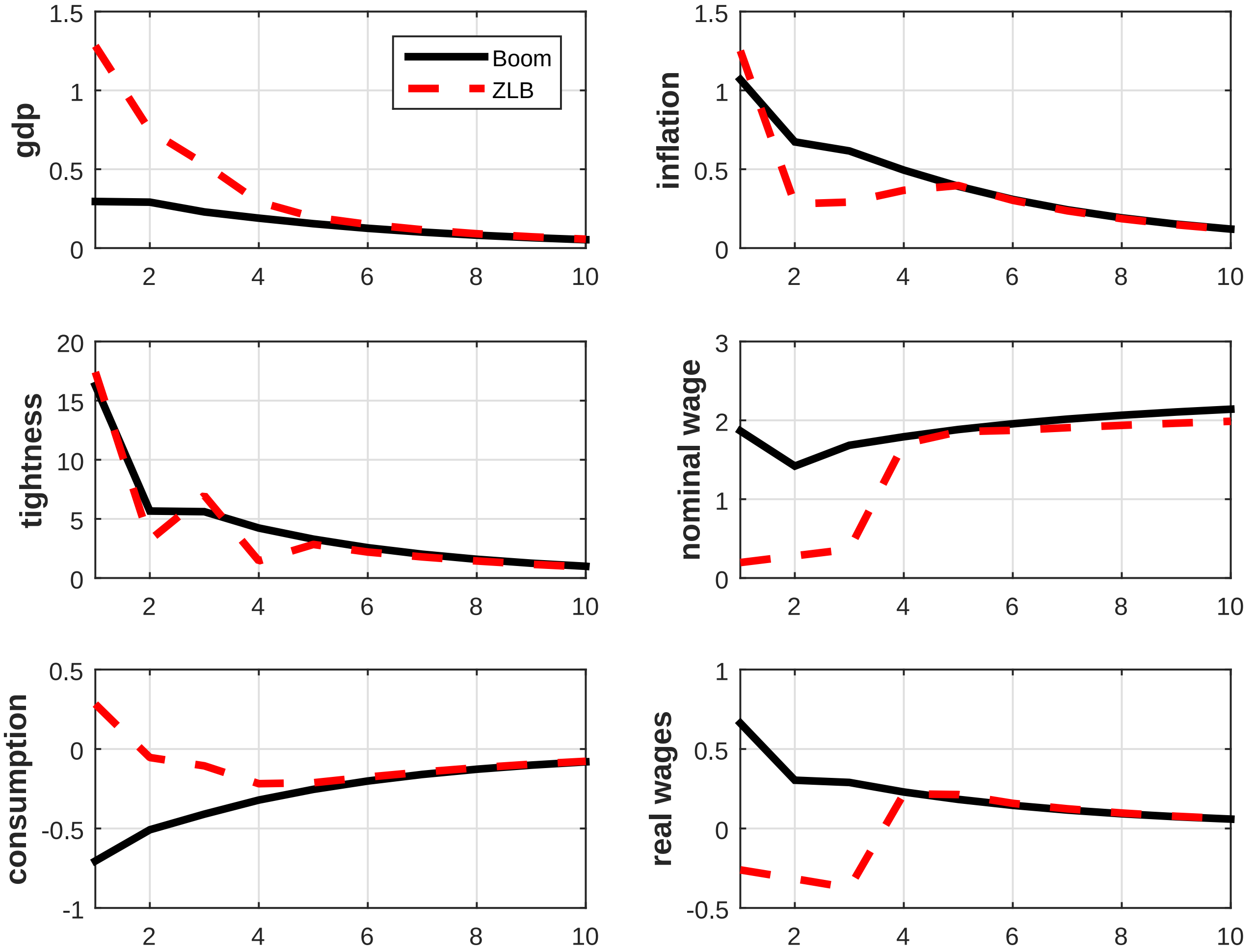
	Expansion	Recession	ZLB
GDP			
2 year Integral	0.37	0.47	0.8
4 year Integral	0.38	0.46	0.76
Inflation			
2 year Integral	0.99	0.85	0.8
4 year Integral	0.98	0.85	0.81

It should be noted that the cumulative multiplier effects on GDP at the ZLB, while twice as big as the ones in expansion are still lower than unity. Therefore, in the model with downward rigid wages, the impact multiplier is much larger than the cumulative one. This is consistent with the baseline empirical specification, in which I found cumulative multipli-

[36] Given the numbers just exposed, keeping in mind that the increase in government spending is $\Delta g \equiv 0.01 \cdot g_{ss}$ and that $g_{ss} \simeq 0.196 \cdot gdp_{ss}$ the impact multiplier effect is equal to $\frac{(1-0.0285)-(1-0.031)}{0.01 \cdot 0.196}$=1.27.

[37] In the Appendix, I consider a related framework in which wage rigidity comes from a credible bargaining setup as in Christiano et al. (2013), which in turn builds on Hall & Milgrom (2008). I show that in this case the multiplier is still higher at the ZLB, with inflation reacting comparatively less than in an expansion. Also, to show that search and matching frictions are essential for this, I solve a version of the model without recruiting costs $r = 0$ and with a separation rate of $s = 1$. In this case, I show that a downward rigid wage without search and matching frictions does not generate meaningful asymmetries.

Figure 8: Impulse Responses to a Government Spending Shock in Boom/ZLB with downward rigid wage.



Notes: The black line represents the difference between the path of GDP/inflation with i) only a positive preference shock and ii) a preference and government spending shock. This difference is then scaled by the initial increase in government spending, so that the response is the multiplier effect of government spending. The red dashed line represents the same but with a negative preference shock.

ers on GDP ranging from 0.64 to 0.77 at the ZLB. The cumulative effects of inflation, while lower than in the model with flexible wages are still higher than what can be found in the data.

Now that I have a framework that can yield both (i) a higher multiplier in a recession and (ii) an even bigger one at ZLB, I can address the following question : How much of the additional multiplier effect at ZLB has to do with the fact that the nominal interest rate cannot go below zero? To answer this question, I keep the same magnitude of the shock, but I simulate the economy without taking into account the ZLB. It follows that the recession will have a binding wage constraint and (possibly) a negative net interest rate.

What I find is that indeed, the net nominal interest is negative and troughs at -6.8% in annualized terms. As a result, the recession is dampened with an GDP decline of only -2.1%. Still, higher government spending further mitigates the fall in GDP and the resulting cumulative multiplier effect at a 2-year (resp. 4 year) horizon is 0.67 (resp. 0.64). Since the cumulative multiplier effect at ZLB is 0.8 (resp. 0.76), the dynamics of the model without the ZLB constraint explain roughly 68% of the cumulative multiplier effect on GDP.[38] These cumulative multipliers are computed over horizons that go beyond the duration of the liquidity trap, which is 3 quarters. As such, these multipliers mix dynamics inside and outside of the ZLB. The impact multiplier is computed for the first period, during which the economy is at the ZLB. In this case, I find that the counterfactual model without ZLB can explain roughly 58% of the additional impact multiplier effect at the ZLB.

All in all, the framework developed here does not single out the ZLB as a drastically different situation. A ZLB episode is merely a large recession with higher than normal unemployment and the fact that monetary policy is unresponsive does not play such an important role.

A known shortcoming of the New Keynesian model is that it predicts a sizable deflation after a negative aggregate demand shock that sends the economy in a liquidity trap. There is ongoing research that tries to show why such a deflation did not materialize during the current Great Recession (See Gordon (2013), Del-Negro et al. (2014) and Coibion & Gorodnichenko (2015)). To the extent that real wages will be higher with deflation in the model with downward nominal wage rigidity, it should dampen the fall in inflation by mitigating the fall in marginal cost. I find that it is indeed the case. I calibrate the preference shock so that it generates the same trough in GDP with and without downward wage rigidity. In both cases, the economy stays in a liquidity trap for 3 periods and GDP troughs at -3.1%. The trough in inflation in the model with flexible wages is -2.61% after such a shock. For a comparable recession, the model with downward wage rigidity predicts a maximum fall in inflation of -1.5%.

[38]For a 2-year horizon, the part of the additional multiplier effect at ZLB explained by the counterfactual model without ZLB is computed as $100 \cdot \frac{0.667-0.37}{0.805-0.37} \simeq 68\%$.

4.4 Discussion

The main channel through which the model generates a limited response of both actual and expected inflation at the ZLB goes through the reaction of the real wage. As can be seen from Figure 8, the real wage actually decreases at the ZLB on impact. In this Figure, I plot the nominal wage instead or real marginal costs to make a link with the wage data that I am going to use. One can see that the nominal wage reacts much less at the ZLB as in a boom, which is due to the downward wage rigidity constraint. To test these predictions, I will study the impact of government spending shocks on the real/nominal wage inside and outside the ZLB.

To the best of my knowledge, there does not exist a quarterly wage series that spans the whole 20th century. Therefore, I combine multiple series to get one that spans the period 1889 to 2015. For the period 1889 to 1914, I use the series constructed in Rees & Jacobs (1961). I use the average annual earnings in all manufacturing (see Chapter 3, Table 10). The annual series is transformed into a quarterly frequency using a cubic spline interpolation. From 1914 to 1694, I use Total Average Weekly Earnings (FRED series #$M08261USM052NNBR$ from the NBER MacroHistory Database). Finally, for the period 1964 to present I use Average Weekly Earnings of Production and Nonsupervisory Employees for the Private Sector (FRED Series #$CEU0500000030$). This series in monthly and aggregated to quarterly frequency. The nominal wage series is then deflated with the GDP Deflator to construct a real wage series. I now use this latter instead of inflation and estimate both equations (2) and (3). As before, I report cumulative multipliers for 2 and 4-year horizons. As the instrument that combines both shocks is the more relevant at ZLB, I use this specification throughout this subsection. In all specifications, I control for taxes. Since the real/nominal wage series is trending over time, I try different specifications to control for that.[39]

One can see from Table 5 that in most specifications the cumulative effects of government spending on both the real and nominal wage is lower at the ZLB than in normal times. When this difference goes the other way around, it is usually not statistically significant, except for one specification. All in all, this provides further evidence for the mechanism that is central to the model with downward wage rigidity, especially at the ZLB. I provide the corresponding cumulative multipliers that the model produces in Table 6. The magnitudes are closer for real wages, while nominal wages react much more than in the data. Still, the model is able to reproduce that the cumulative effects of government spending on both real and nominal wages is smaller at the ZLB than in a boom. Ultimately, these comparisons should be taken with a grain of salt, mainly because of the nature of the wage data which is highly imperfect.

[39] More specifically, I first add linear and quadratic trends. A common practice in the DSGE literature is to deflate real/nominal wages using the trending component of technology. The closest measure available here is the potential level of output, which I use to deflate both wage series. As these deflated series trend downward over time, I keep linear and quadratic trends in these specifications.

Table 5: Estimates of Nominal/Real Wage Multipliers Across Monetary Regimes: Robustness Analysis

Nominal Wage

	Linear Model	Normal	Zero Lower Bound	P-Value
Log Wage				
2 year Integral	0.25 (0.16)	0.85 (0.35)	0.46 (0.14)	0.28
4 year Integral	0.68 (0.23)	1.63 (0.79)	0.62 (0.14)	0.2
Log Wage, Linear + Quadratic trends				
2 year Integral	0.19 (0.16)	1.2 (0.32)	0.43 (0.13)	0.02**
4 year Integral	0.58 (0.22)	2.54 (0.98)	0.54 (0.13)	0.04**
Wage/Potential Output				
2 year Integral	0.004 (0.004)	0.03 (0.01)	0.01 (0.002)	0.03**
4 year Integral	0.014 (0.006)	0.07 (0.03)	0.01 (0.002)	0.067*

Real Wage

Log Wage				
2 year Integral	0.39 (0.07)	0.36 (0.06)	0.49 (0.03)	0.03**
4 year Integral	0.52 (0.04)	0.58 (0.18)	0.5 (0.04)	0.67
Log Wage, Linear + Quadratic trends				
2 year Integral	0.39 (0.07)	0.46 (0.05)	0.5 (0.03)	0.5
4 year Integral	0.54 (0.04)	0.91 (0.17)	0.5 (0.04)	0.0098***
Wage/Potential Output				
2 year Integral	0.09 (0.01)	0.1 (0.02)	0.12 (0.007)	0.49
4 year Integral	0.13 (0.01)	0.17 (0.04	0.12 (0.007)	0.24

Table 6: Cumulative GDP/Inflation Multipliers Across States in the Model with Downward Rigid Wages

	Boom	ZLB
Nominal Wage		
2 year Integral	3.89	2.8
4 year Integral	7.1	5.85
Real Wage		
2 year Integral	0.49	-0.01
4 year Integral	0.48	0.04

5 Conclusion

In this paper I have focused on how the setup of the labor market plays a role in the transmission mechanisms of government spending in a recession which is possibly big enough to generate a liquidity trap. I have developed a model that is able to reproduce the cumulative multipliers on GDP and inflation found in the data. I have also shown that when one takes into account the fact that a liquidity trap is always associated with an unemployment crisis, higher government spending can be a good tool to stimulate GDP. This comes only partially from the fact that government spending is inflationary, but more importantly from the fact that recruiting additional workers is much easier in a severe recession.

All in all, government spending does not seem to be the right tool to generate inflation in a liquidity trap. As a consequence, the virtuous cycle on inflation and the real interest rate does not play an important role. The government spending multiplier is indeed unusually large in a liquidity trap, but a substantial part of the multiplier effects of government spending at the ZLB has nothing to do with the fact that monetary policy is unresponsive.

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A Simple New Keynesian Model

The simple New Keynesian model that I use in section 2 is a special case of the one developed in Albertini et al. (2014), albeit with only non-productive government spending. It features Rotemberg-type quadratic price adjustment costs. The production function has constant returns to scale and the household has a standard utility function

$$U(C_t, N_t) = \frac{C_t^{1-\sigma}}{1-\sigma} - \chi \frac{N_t^{1+\varphi}}{1+\varphi}.$$

I only report the equilibrium conditions here and refer the interested reader to the aforementioned paper for more details.

A.1 Summary of the model

The model can be summarized by the following set of equations:

$$\begin{aligned}
N_t &= C_t + G_t + N_t \frac{\phi}{2} (\Pi_t/\Pi)^2 && (18)\\
1 &= R_t \mathcal{E}^1_{t+1} && (19)\\
\epsilon \cdot MC_t &= \epsilon - 1 + \phi(\Pi_t/\Pi - 1)(\Pi_t/\Pi) - \phi \mathcal{E}^2_{t+1} && (20)\\
MC_t &= \chi N_t^{\varphi} C_t^{\sigma} && (21)\\
R_t &= \max\left\{1, \frac{\Pi}{\beta}\left(\frac{\Pi_t}{\Pi}\right)^{\phi_\pi}\right\}. && (22)
\end{aligned}$$

where the expectation functions are given by:

$$\begin{aligned}
\mathcal{E}^1_{t+1} &= \mathbb{E}_t \frac{\Lambda_{t,t+1}}{\Pi_{t+1}} && (23)\\
\mathcal{E}^2_{t+1} &= \mathbb{E}_t \left\{\Lambda_{t,t+1} \frac{Y_{t+1}}{Y_t} \frac{\Pi_{t+1}}{\Pi} \left(\frac{\Pi_{t+1}}{\Pi} - 1\right)\right\} && (24)\\
& && (25)
\end{aligned}$$

where

$$\Lambda_{t,t+1} = \beta \xi_{t+1} \left[\frac{C_{t+1}}{C_t}\right]^{-\sigma}.$$

B Tables

Table 7: Estimates of GDP/Inflation Multipliers Across Monetary Regimes: Excluding World War II

GDP

	Linear Model	Normal	Zero Lower Bound	P-Value
Military News Shock				
2 year Integral	0.77 (0.2)	0.63 (0.15)	1.4 (0.15)	0.000***
4 year Integral	0.74 (0.16)	0.77 (0.37)	0.98 (0.1)	0.58
Blanchard Perotti Shock				
2 year Integral	0.13 (0.08)	0.1 (0.1)	1.08 (0.75)	0.2
4 year Integral	0.15 (0.09)	0.12 (0.11)	0.84 (0.57)	0.23
Combined				
2 year Integral	0.21 (0.09)	0.26 (0.1)	1.6 (0.51)	0.01***
4 year Integral	0.26 (0.1)	0.21 (0.14)	1.1 (0.23)	0.001***

Inflation

	Linear Model	Normal	Zero Lower Bound	P-Value
Military News Shock				
2 year Integral	0.94 (0.1)	1.07 (0.2)	0.91 (0.1)	0.44
4 year Integral	0.57 (0.27)	0.98 (0.23)	0.24 (0.08)	0.002***
Blanchard Perotti Shock				
2 year Integral	0.25 (0.14)	0.32 (0.11)	0.12 (0.23)	0.38
4 year Integral	0.21 (0.13)	0.27 (0.1)	0.01 (0.21)	0.24
Combined				
2 year Integral	0.4 (0.14)	0.57 (0.14)	0.52 (0.2)	0.81
4 year Integral	0.35 (0.12)	0.47 (0.12)	0.2 (0.08)	0.049**

Table 8: Estimates of GDP/Inflation Multipliers Across Monetary Regimes: Robustness Analysis

GDP

	Linear Model	Normal	Zero Lower Bound	P-Value
Defining ZLB as T-bill ≤ 0.5				
2 year Integral	0.42 (0.1)	0.25 (0.08)	0.62 (0.05)	0.000***
4 year Integral	0.56 (0.08)	0.31 (0.1)	0.73 (0.05)	0.000***
Controls for Taxes				
2 year Integral	0.42 (0.12)	0.21 (0.15)	0.71 (0.035)	0.001***
4 year Integral	0.58 (0.09)	0.04 (0.25)	0.8 (0.03)	0.003***
Controls for Debt				
2 year Integral	0.44 (0.09)	0.43 (0.11)	0.77 (0.04)	0.005***
4 year Integral	0.58 (0.07)	0.38 (0.15)	0.81 (0.04)	0.008***

Inflation

	Linear Model	Normal	Zero Lower Bound	P-Value
Defining ZLB as T-bill ≤ 0.5				
2 year Integral	0.05 (0.12)	0.42 (0.13)	-0.05 (0.08)	0.002***
4 year Integral	0.12 (0.09)	0.37 (0.12)	0.09 (0.02)	0.02**
Controls for Taxes				
2 year Integral	0.06 (0.13)	0.63 (0.16)	0.001 (0.08)	0.002***
4 year Integral	0.12 (0.09)	0.37 (0.12)	0.09 (0.02)	0.001***
Controls for Debt				
2 year Integral	0.07 (0.13)	0.74 (0.12)	0.09 (0.1)	0.000***
4 year Integral	0.15 (0.1)	0.6 (0.11)	0.11 (0.02)	0.000***

C Computational Details

C.1 The Bargaining Problem

The wage bargaining problem with the downward rigidity constraint can be represented by the following Lagrangian:

$$\mathcal{L}_t \equiv (1-\mu)\log(\tilde{V}_{N,t}) + \mu\log(V_{J,t}) + \lambda_t^w(\mathcal{W}_t - \underline{\mathcal{W}}_t) \tag{26}$$

Taking the derivative with respect to $\mathcal{W}_t$ and multiplying by $\tilde{V}_{N,t} \cdot \frac{r}{q(\theta_t)}$, I get:

$$\begin{aligned}(1-\mu)\frac{r}{q(\theta_t)} &= \left[\mu - \lambda_t^w \frac{r}{q(\theta_t)}\right]\tilde{V}_{N,t} \\ \Leftrightarrow \tilde{V}_{N,t} &= (1-\mu)\frac{\frac{r}{q(\theta_t)}}{\mu - \lambda_t^w \frac{r}{q(\theta_t)}}\end{aligned} \tag{27}$$

Using this equation alongside the household's first order condition with respect to N_t, I can thus express $\tilde{V}_{N,t}$ as

$$\begin{aligned}\tilde{V}_{N,t} &= W_t - b - \chi\frac{N_t^{\varphi}}{C_t^{-\sigma}} + (1-s)\mathbb{E}_t\Lambda_{t,t+1}\tilde{V}_{N,t+1} \\ &= W_t - b - \chi\frac{N_t^{\varphi}}{C_t^{-\sigma}} + (1-s)\mathbb{E}_t\Lambda_{t,t+1}(1-f(\theta_{t+1}))(1-\mu)\frac{\frac{r}{q(\theta_{t+1})}}{\mu - \lambda_{t+1}^w \frac{r}{q(\theta_{t+1})}}\end{aligned} \tag{28}$$

Likewise, from the firm's FOC with respect to N_t, I can express $\frac{r}{q(\theta_t)}$ as

$$\frac{r}{q(\theta_t)} = MC_t - \mathcal{W}_t + (1-s)\mathbb{E}_t\Lambda_{t,t+1}\frac{r}{q(\theta_{t+1})} \tag{29}$$

Using equations (28) and (29) to substitute for $\tilde{V}_{N,t}$ and $\frac{r}{q(\theta_t)}$ in equation (27), after some algebra I get:

$$
\begin{aligned}
\mathcal{W}_t &= \mu\left(b+\chi\frac{N_t^{\varphi}}{C_t^{-\sigma}}\right)+(1-\mu)MC_t+(1-s)(1-\mu)\mathbb{E}_t\Lambda_{t,t+1}\frac{r}{q(\theta_{t+1})} \\
&+\lambda_t^w\frac{r}{q(\theta_t)}\tilde{V}_{N,t}-(1-s)\mathbb{E}_t\Lambda_{t,t+1}\left\{\mu(1-f(\theta_{t+1}))\frac{(1-\mu)\frac{r}{q(\theta_{t+1})}}{\mu-\frac{r\lambda_{t+1}^w}{q(\theta_{t+1})}}\right\} \\
&= \mu\left(b+\chi\frac{N_t^{\varphi}}{C_t^{-\sigma}}\right)+(1-\mu)MC_t+(1-s)(1-\mu)\mathbb{E}_t\Lambda_{t,t+1}r\cdot\frac{f(\theta_{t+1})}{q(\theta_{t+1})} \\
&+\lambda_t^w\frac{r}{q(\theta_t)}\tilde{V}_{N,t}+(1-s)(1-\mu)\mathbb{E}_t\Lambda_{t,t+1}(1-f(\theta_{t+1}))\frac{r}{q(\theta_{t+1})}\left\{\frac{\lambda_{t+1}^w}{1-\frac{\mu q(\theta_{t+1})}{r}}\right\} \\
&= \mu\left(b+\chi\frac{N_t^{\varphi}}{C_t^{-\sigma}}\right)+(1-\mu)MC_t+(1-s)(1-\mu)\mathbb{E}_t\Lambda_{t,t+1}r\cdot\theta_{t+1} \\
&+\lambda_t^w\frac{r}{q(\theta_t)}\tilde{V}_{N,t}+(1-s)(1-\mu)\mathbb{E}_t\Lambda_{t,t+1}(1-f(\theta_{t+1}))\frac{r}{q(\theta_{t+1})}\left\{\frac{\lambda_{t+1}^w}{1-\frac{\mu q(\theta_{t+1})}{r}}\right\} \\
&\equiv \mathcal{W}_t^{flex}+\lambda_t^w\frac{r}{q(\theta_t)}\tilde{V}_{N,t} \\
&+(1-s)(1-\mu)\mathbb{E}_t\Lambda_{t,t+1}(1-f(\theta_{t+1}))\frac{r}{q(\theta_{t+1})}\left\{\frac{\lambda_{t+1}^w}{1-\frac{\mu q(\theta_{t+1})}{r}}\right\}
\end{aligned}
$$

Alternatively, if I regroup all $t+1$ terms, I get:

$$
\begin{aligned}
\mathcal{W}_t = \mu\left(b+\chi\frac{N_t^{\varphi}}{C_t^{-\sigma}}\right)+r\frac{\lambda_t^w\tilde{V}_{N,t}}{q(\theta_t)} \\
+(1-\mu)\left(MC_t+(1-s)\mathbb{E}_t\Lambda_{t,t+1}\left(1-\frac{\mu(1-f(\theta_{t+1}))}{\mu-r\frac{\lambda_{t+1}^w}{q(\theta_{t+1})}}\right)\right).
\end{aligned}
$$

While the comparison with the flexible wage is less clear with this expression, it has only one expectation term to approximate, so I use this equation when computing the equilibrium.

C.2 Summary of the model

The model can be summarized by the following set of equations:

$$
\begin{aligned}
N_t &= (1-s)N_{t-1} + \big[1-(1-s)N_{t-1}\big]f(\theta_t) && (30)\\
N_t &= C_t + G_t + [N_t - (1-s)N_{t-1}]\frac{r}{q(\theta_t)} + N_t\frac{\phi}{2}(\Pi_t/\Pi)^2 && (31)\\
1 &= R_t\mathcal{E}^1_{t+1} && (32)\\
\epsilon\cdot MC_t &= \epsilon - 1 + \phi(\Pi_t/\Pi - 1)(\Pi_t/\Pi) - \phi\mathcal{E}^2_{t+1} && (33)\\
MC_t &= \mathcal{W}_t + \frac{r}{q(\theta_t)} - (1-s)E_t\mathcal{E}^3_{t+1} && (34)\\
R_t &= \max\left\{1, \frac{\Pi}{\beta}\left(\frac{\Pi_t}{\Pi}\right)^{\phi_\pi}\right\}. && (35)\\
\mathcal{W}_t &= \mu\left(b + \chi\frac{N_t^{\varphi}}{C_t^{-\sigma}}\right) + r\frac{\lambda_t^w\tilde{V}_{N,t}}{q(\theta_t)} + (1-\mu)\left(MC_t + (1-s)\mathcal{E}^4_{t+1}\right), && (36)
\end{aligned}
$$

where the expectation functions are given by:

$$
\begin{aligned}
\mathcal{E}^1_{t+1} &= \mathbb{E}_t\frac{\Lambda_{t,t+1}}{\Pi_{t+1}} && (37)\\
\mathcal{E}^2_{t+1} &= \mathbb{E}_t\left\{\Lambda_{t,t+1}\frac{Y_{t+1}}{Y_t}\frac{\Pi_{t+1}}{\Pi}\left(\frac{\Pi_{t+1}}{\Pi} - 1\right)\right\} && (38)\\
\mathcal{E}^3_{t+1} &= \mathbb{E}_t\left\{\Lambda_{t,t+1}\frac{r}{q(\theta_{t+1})}\right\} && (39)\\
\mathcal{E}^4_{t+1} &= \mathbb{E}_t\Lambda_{t,t+1}\left(1 - \frac{\mu(1-f(\theta_{t+1}))}{\mu - r\frac{\lambda^w_{t+1}}{q(\theta_{t+1})}}\right), && (40)
\end{aligned}
$$

where

$$\Lambda_{t,t+1} = \beta\xi_{t+1}\left[\frac{C_{t+1}}{C_t}\right]^{-\sigma}.$$

C.3 Solution Algorithm

The Parameterized Expectation Algorithm amounts to approximate the expectation functions by a simple polynomial function of the state variables. The polynomials I consider will be of the Chebychev type. Accordingly, for a state variable $s_t \in S_t$ let $C_i : s_t \longmapsto C_i(s_t)$ be the function that returns the Chebychev polynomial of order $i \in \mathbb{N}$ evaluated at the point s_t. I first build a linearly spaced grid of the state variables centered on the steady state value for each one. I then evaluate $C_i(.)$ at each point of the grid. For a given polynomial degree p (I choose $p = 3$ in the simulations) and for each grid point, I construct a modified grid which is composed of the products of $C_i(.)$ evaluated at different grid points, with the restriction that the product should be of degree less or equal than p. For example, I take the first grid point for each state variable, I evaluate each one with $C_1(.), \dots C_p(.)$, keeping only the products of degree less or equal than p. This gives me the first line of the final grid. For the second line, I take the same points but the last one is the second grid point of the last state variable, and so and so on. I end up with a grid $\tilde{S} \in \mathbb{R}^{(p+1)^s}$, with s being the number of state variables.

The expectation functions are approximated by a simple function of the Chebychev polynomials of the state variables, namely:

$$\mathcal{E}^i_{t+1} = \tilde{S}_t \cdot \Xi^i, \quad i = \{1, 2, 3\},$$

where Ξ^i has no time subscript since it is a time-invariant "'policy rule"'. Let Ξ denote $[\Xi^1, \Xi^2, \Xi^3]$. This is the object on which I will iterate until convergence. The endogenous variables will also be expressed as a function of the Chebychev polynomials of the states. It is sufficient to approximate the policy rules for two of the endogenous variables : the labor market tightness θ_t and the inflation rate Π_t. Given expectations and the states variables, all the other endogenous variables can be computed. Let Ω be the set of coefficients that relates θ_t and Π_t to the Chebychev polynomials of the state variables. The algorithm then works as follows:

1. Choose a value for the learning parameter $\zeta \in [0, 1]$ and the stopping criterion, ϵ.
2. Start with an initial guess for Ξ, say Ξ_0. As a first guess, I evaluate the expectations functions at steady state.
3. For each point of the grid on state values, compute the value of the expectations. Given a first guess for Ω_0, compute Ω using a Newton algorithm. [40]
4. Using Ω and the law of motion of the state variables, reevaluate the expectations functions using a Gauss-Hermite quadrature.
5. Regress these new expectations on the grid of state variables, which gives Ξ_1.
6. Compute $\hat{\Xi}_1 = \zeta\Xi_1 + (1 - \zeta)\Xi_0$
7. If $\left\| \frac{\hat{\Xi}_1 - \Xi_0}{\Xi_0} \right\| < \epsilon$ then stop. Else return to step 2, using $\hat{\Xi}_1$ and the last solution for Ω as guesses.

[40] I actually compute four policy rules : one for each case given the two occasionally binding constraints.

D Calibration

Table 9: CALIBRATION

Steady-State Target	Symbol	Value	Source
Annual steady state inflation	π	0.02	Standard
Steady state job filling rate	q	0.7	Ravenna & Walsh (2008)
Steady state unemployment	u	0.064	Michaillat (2014) (JOLTS 2001-2011)
Parameter	**Symbol**	**Value**	**Source**
Discount factor	β	0.994	Match annual interest rate of 2.5%
Price adjustment	ψ	60	Match Calvo probability of 0.75
Matching efficiency	m	0.657	Match $q = 0.7$
Elast. of subst. between goods	ϵ	6	Markup of 20%
Recruiting cost	r	0.0636	1% of steady state output
Government spending share	g	0.2	Average post WW II in USA
Response to inflation	ϕ_π	1.5	Standard
Matches/seekers elasticity	η	0.5	Pissarides & Petrongolo (2001)
Firm bargaining power	μ	0.5	Hosios (1990)
Separation rate	s	0.11	Krause et al. (2008)
Replacement rate	b	0.4	Ravenna & Walsh (2008)
Risk aversion coefficient	σ	1	Christiano et al. (2011)
Labor disutility	φ	1	Fernández-Villaverde et al. (2015)

E Simulations

Figure 9: Effects of a 1% Increase in Government Spending, Standard New Keynesian Model with $\varphi = 4$

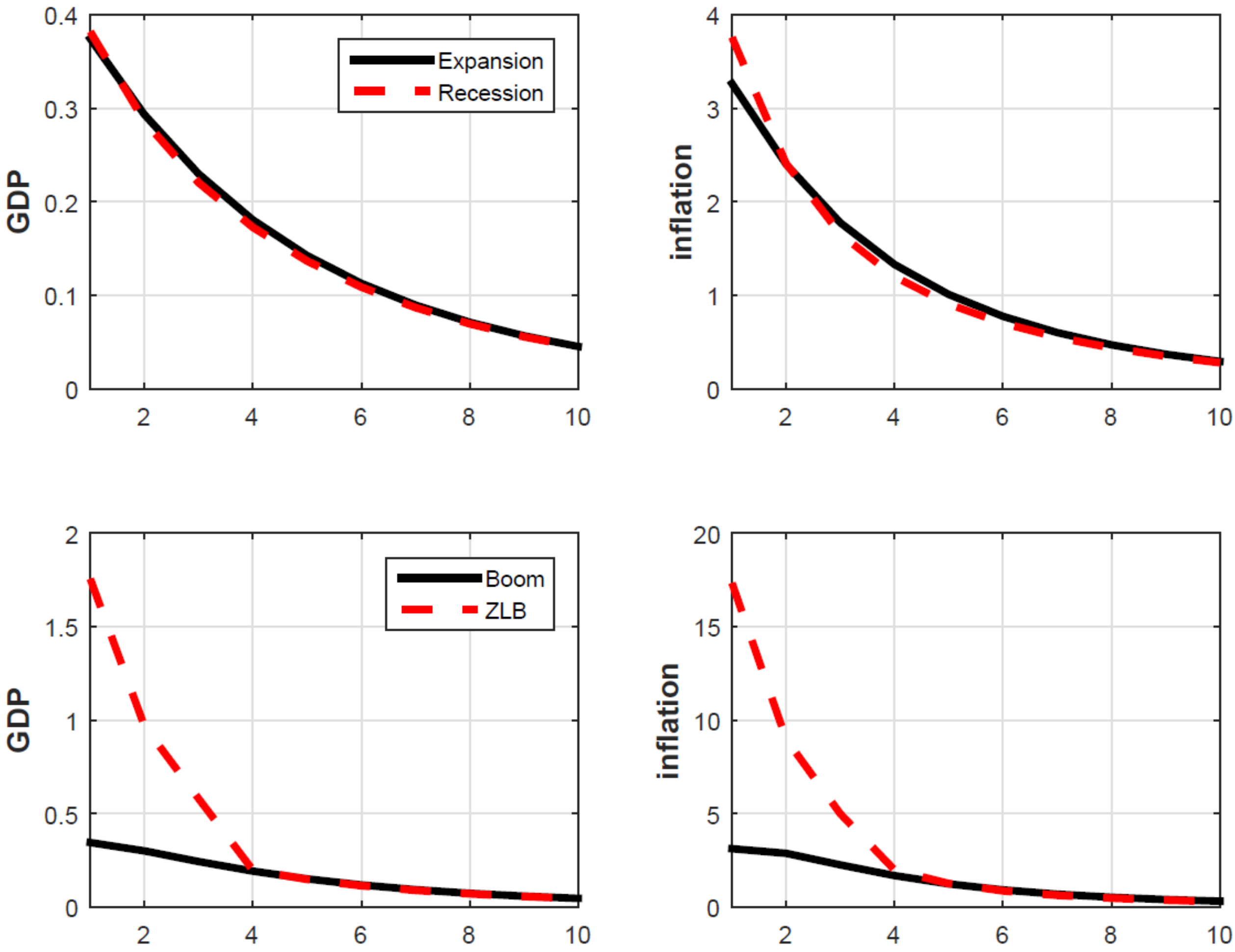


Figure 10: ZLB/Boom with and without Government Spending Shocks with flexible wage. Both variables are scaled by their respective steady state value.

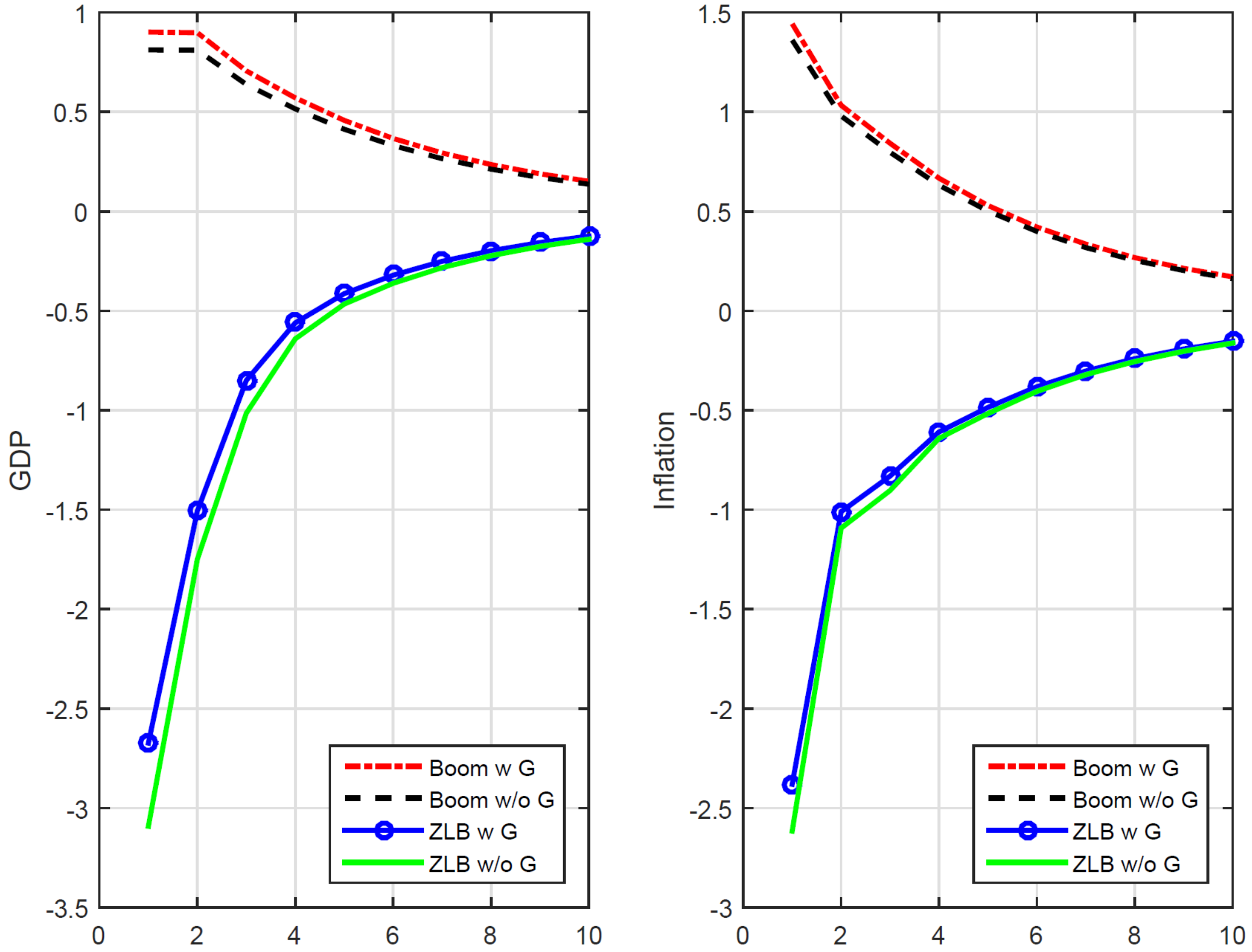
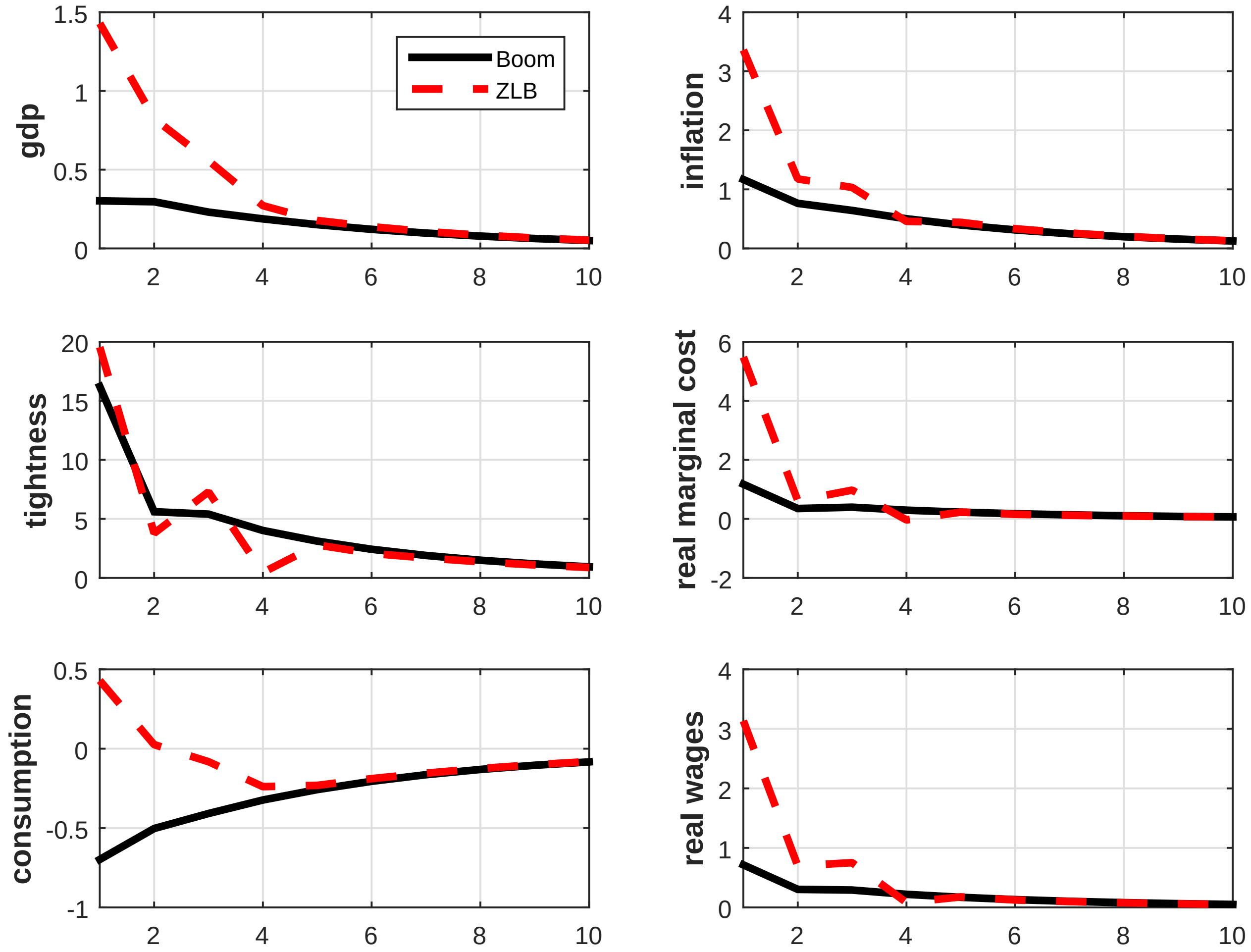


Figure 11: Impulse Response to a Government Spending Shock in ZLB/Boom Periods



E.1 Policy rules

Figure 12: Policy rules for the model with downward rigid nominal wages as a function of preference shock

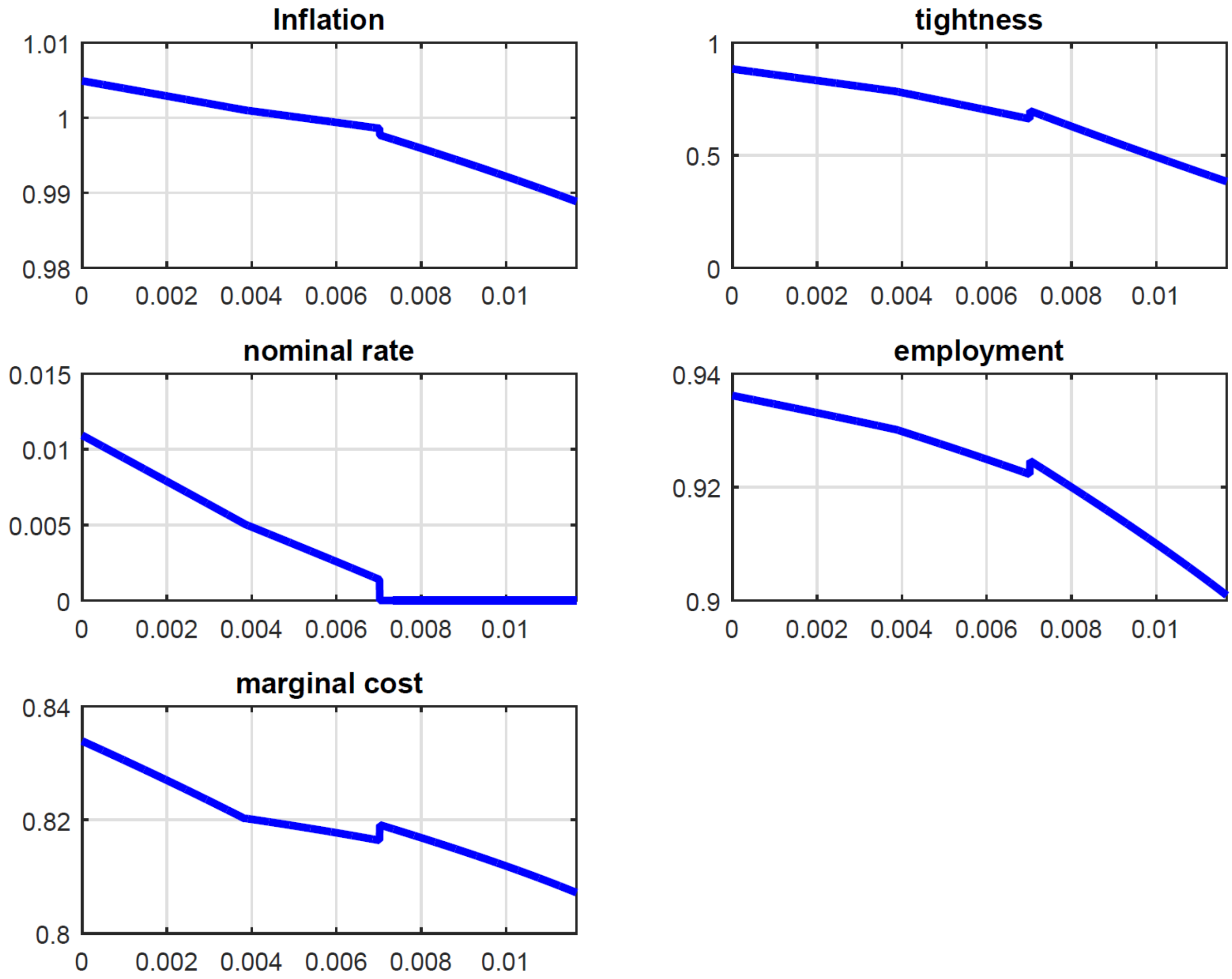
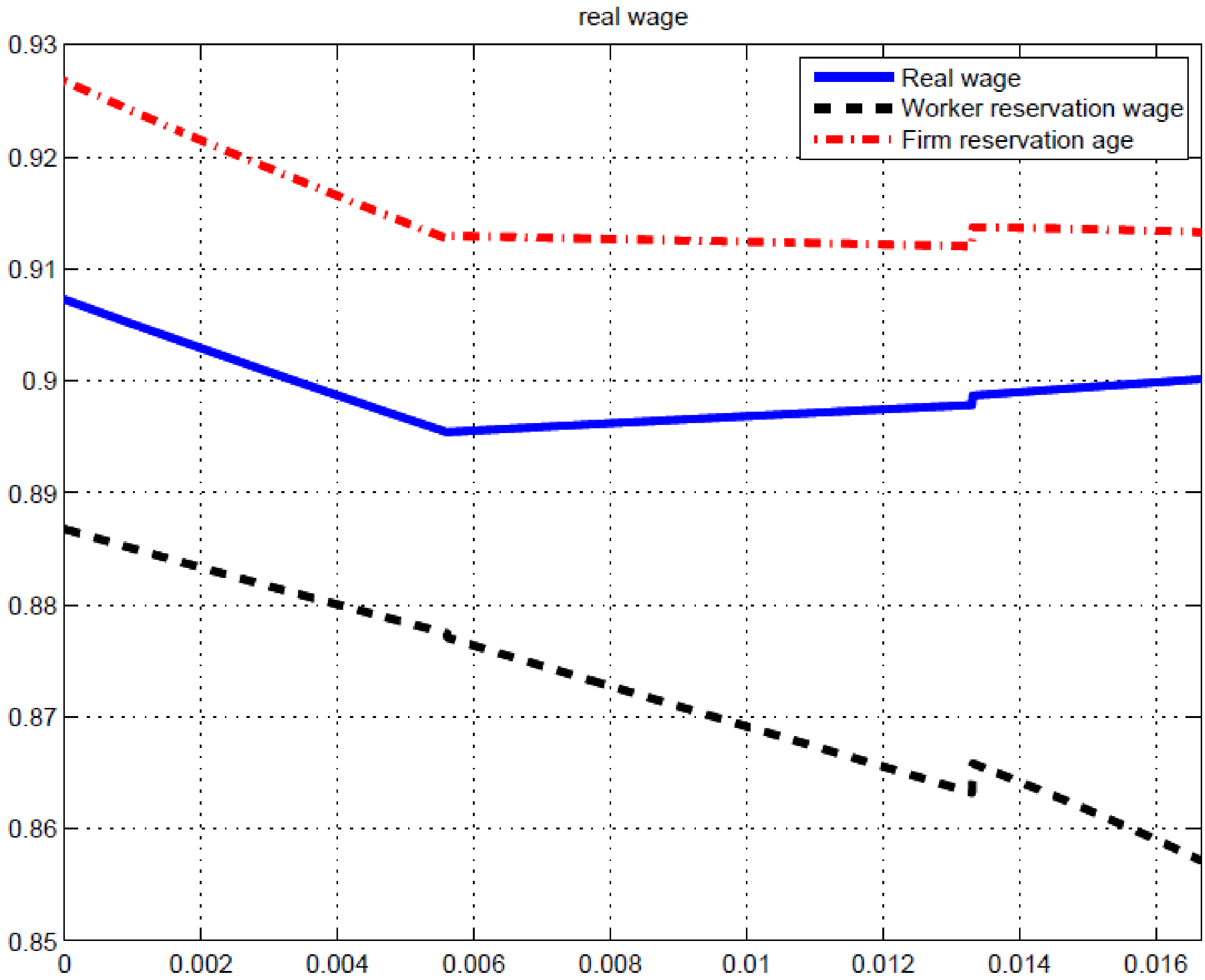


Figure 13: Policy rules for real wage and bargaining set as a function of preference shock



F Robustness Analysis

In the previous subsection, I have highlighted the role of search and matching frictions and a downward rigid wage jointly. But it could well be that the assumption of a downward rigid wage—independently from search and matching frictions—is sufficient to get the same result. To really pinpoint the role of a downward rigid wage, I will study a simplified version of the model in which recruitment costs play no role and the level of employment is no longer a state variable. Formally, I assume that the vacancy posting cost parameter is equal to $r = 0$. I also assume that the separation rate is equal to $s = 1$. Both of these assumptions imply that the real wage is equal to the reservation wage of the wholesale firm. It also implies that the level of employment is entirely determined by the level of labor market tightness. I report in the appendix (see Figure 15) the response of a one standard shock to government spending when the economy is sent at the ZLB for 4 periods.

What stands out of Figures 14 and 15 is the fact that the effects of government spending are not that different in an expansion versus in a recession. Absent vacancy posting costs and employment duration within the firm, the incentives to post vacancies are roughly the same whether the economy is in a recession or not. This result is consistent with the analysis in Michaillat & Saez (2016). They show that a matching market without recruiting cost is isomorphic to a disequilibrium market. In this setup, the multiplier does not depend on the level of unemployment.[41] These responses do not accord well with the empirical evidence that I presented and therefore the simulations at the ZLB for this model should be taken with a grain of salt. It turns out that the results of these simulations are mainly driven by the assumption of downward wage rigidity and still generate a low reaction of inflation.

In addition, even though it seems to be borne out by a large body of empirical evidence, the assumption of downward rigid nominal wage has some shortcomings. First and foremost, it is imposed ad hoc and does not come from first principles. It is not sure then why the agents will come to choose this type of wage agreement instead of every other one for which the real wage stays in the bargaining set. Since the real wage plays an important role in determining real marginal costs, it could be that the particular assumptions on wage rigidity might play an important role.

Accordingly, I consider a model where the real wage is rigid not because of an ad-hoc constraint, but because of how firms and workers negotiate. Specifically, I consider the simple model developed in Christiano et al. (2013), which in turn builds on Hall & Milgrom (2008). The firms and workers negotiate following the alternating offer bargaining scheme developed in Rubinstein (1982). As in Hall & Milgrom (2008), the inertia of real wages comes from the fact that the costs of bargaining are relatively insensitive to business cycle fluctuations. There is no presumption in this setup about whether real wages are more rigid going downward or upward.

Because my focus is again on the non-linearity inherent to the matching setup between job seekers and vacancies, I solve the model using the PEA algorithm. I use the same calibration as Christiano et al. (2013), with one slight modification. To avoid having one more state variable for the dispersion of prices, I assume that firms face price adjustment costs as in Rotemberg (1982) instead of the Calvo (1983) framework employed in their paper. I set $\phi = 96$ for the price rigidity parameter, again to target a Calvo parameter of 0.8 with the value for the elasticity of substitution across goods taken by Christiano et al. (2013). I show the policy rules for the main variables of interest in Figure 16 (in the appendix) as a function of the preference shock.

The main takeaway from Figure 16 is the fact that the policy rules for labor market tightness, real marginal cost and thus, inflation are non-linear. Therefore, as in the model with downward nominal wage rigidity, whether the increase in government spending will occur in a boom or in a recession it will have different effects on those variables. Another feature to be noted is that the kink coming from the ZLB does not seem to impact their respective shape. As a result, the effect of government spending on those variables at the ZLB will be roughly the same as if it were only a big recession. It is clear in Figure 17, where I show the

[41] I thank an anonymous referee for suggesting this reference.

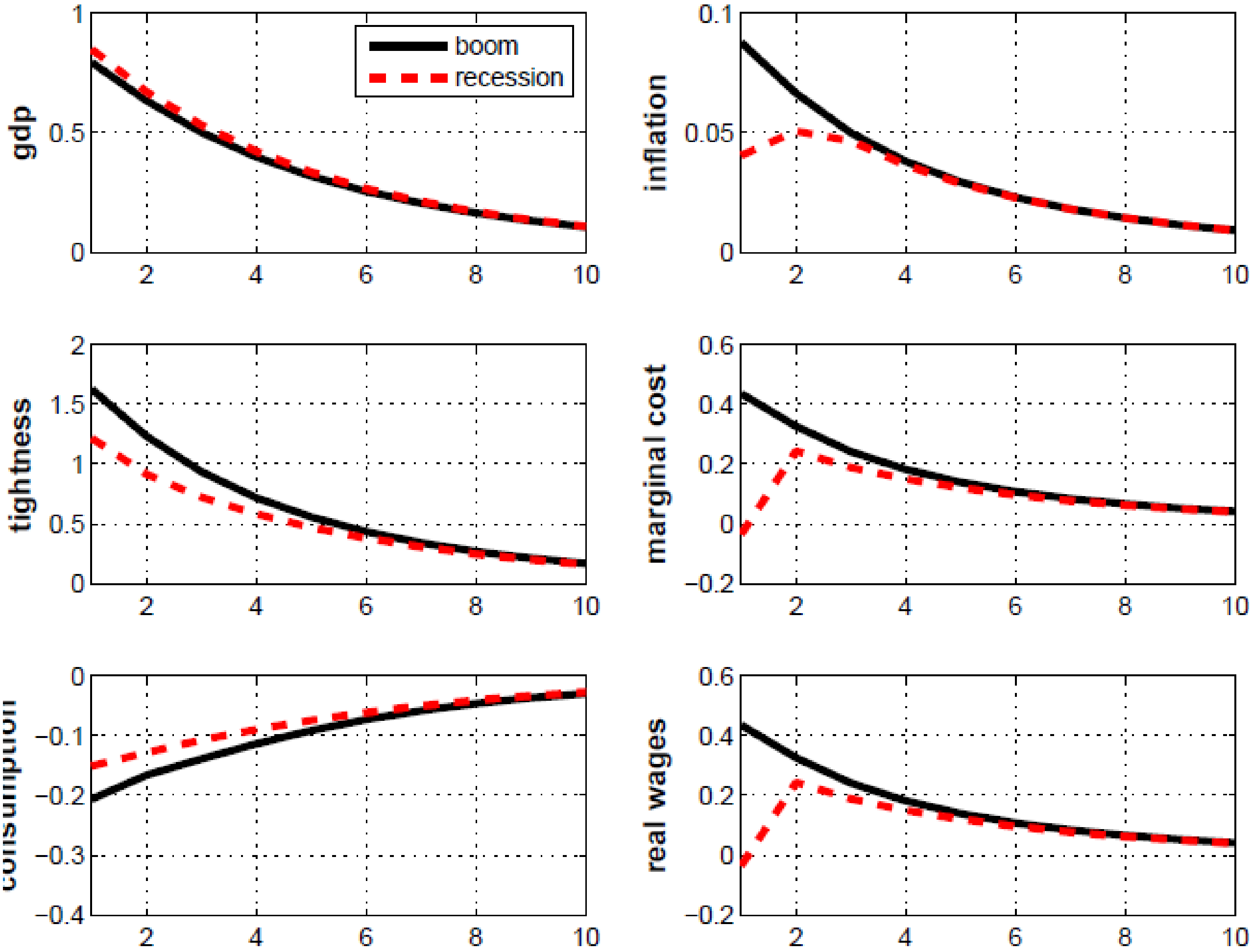
multiplier effects of government spending in a recession (after a negative aggregate demand shock that is not big enough to send the economy to the ZLB) and in a boom (following a preference shock of opposite sign that generates higher output, employment, inflation etc.).

Labor market tightness and real marginal costs react much less in a recession, which generates a lower rise in inflation. Since the Taylor principle is active, lower inflation calls for a lower increase in the nominal rate and thus consumption and GDP rise more than in an expansion. This increase is modest, to say the least, especially compared to the one obtained with my baseline model. This comes from the fact that the bargaining setup in Christiano et al. (2013) makes real marginal costs more sluggish. As a result, inflation reacts very little to a government spending shock and the crowding out effect on private consumption is minimal. In the expansion case, this generates an impact multiplier on GDP of approximately 0.8. Since private consumption necessarily decreases after a government spending shock outside the ZLB, there is not much room for a substantially higher multiplier in a recession.

In Figure 18, I show the same picture but this time the recessionary preference shock is big enough to send the economy at the ZLB for one period. In this case, government spending has even less effect on labor market tightness, real marginal cost and inflation. Thus the crowding out effect on private consumption is nil and the multiplier effect on GDP is just equal to 1, *i.e* the increase in government spending. I have tried with more flexible prices so that the economy will stay longer at the ZLB (up to 6 quarters for $\phi = 40$). Even in this case, the multiplier effect of government spending at the ZLB does not exceed one. What remains true also is the fact that a government spending shock in a deep recession (and *a fortriori* in a liquidity trap) generates little if no inflation.

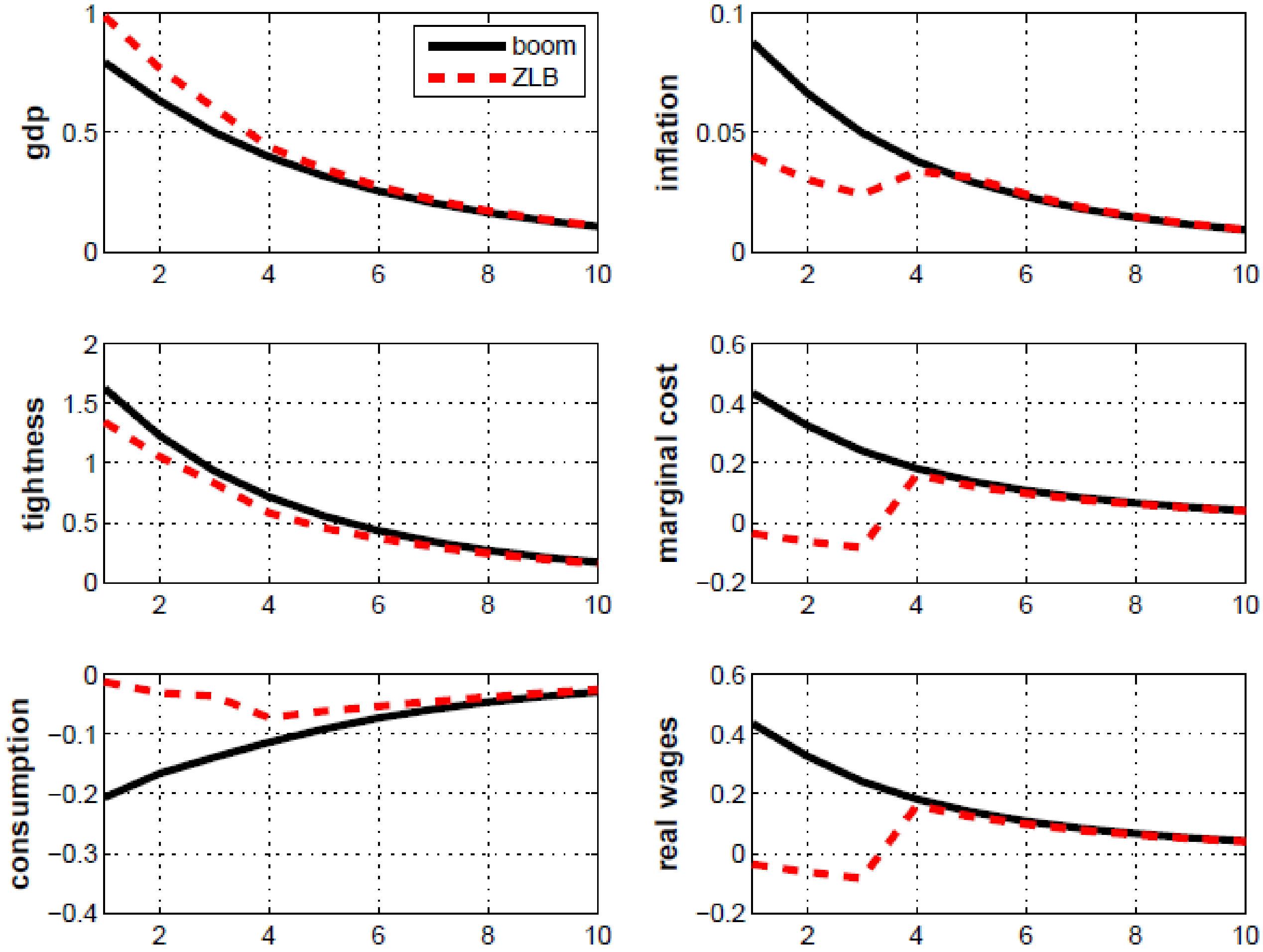
F.1 Downward rigid wages without labor market frictions

Figure 14: Spending multiplier in the model with downward rigid wages without labor market frictions in a recession



Notes: The black line represents the difference between the path of GDP/inflation with i) only a positive preference shock and ii) a preference and government spending shock. This difference is then scaled by the initial increase in government spending, so that the response is the multiplier effect of government spending. The red dashed line represents the same but with a negative preference shock.

Figure 15: Spending multiplier in the model with downward rigid wages without labor market frictions in a liquidity trap



Notes: The black line represents the difference between the path of GDP/inflation with i) only a positive preference shock and ii) a preference and government spending shock. This difference is then scaled by the initial increase in government spending, so that the response is the multiplier effect of government spending. The red dashed line represents the same but with a negative preference shock.

F.2 Model with Credible Bargaining

Figure 16: Policy Rules for the Model with Credible Bargaining.

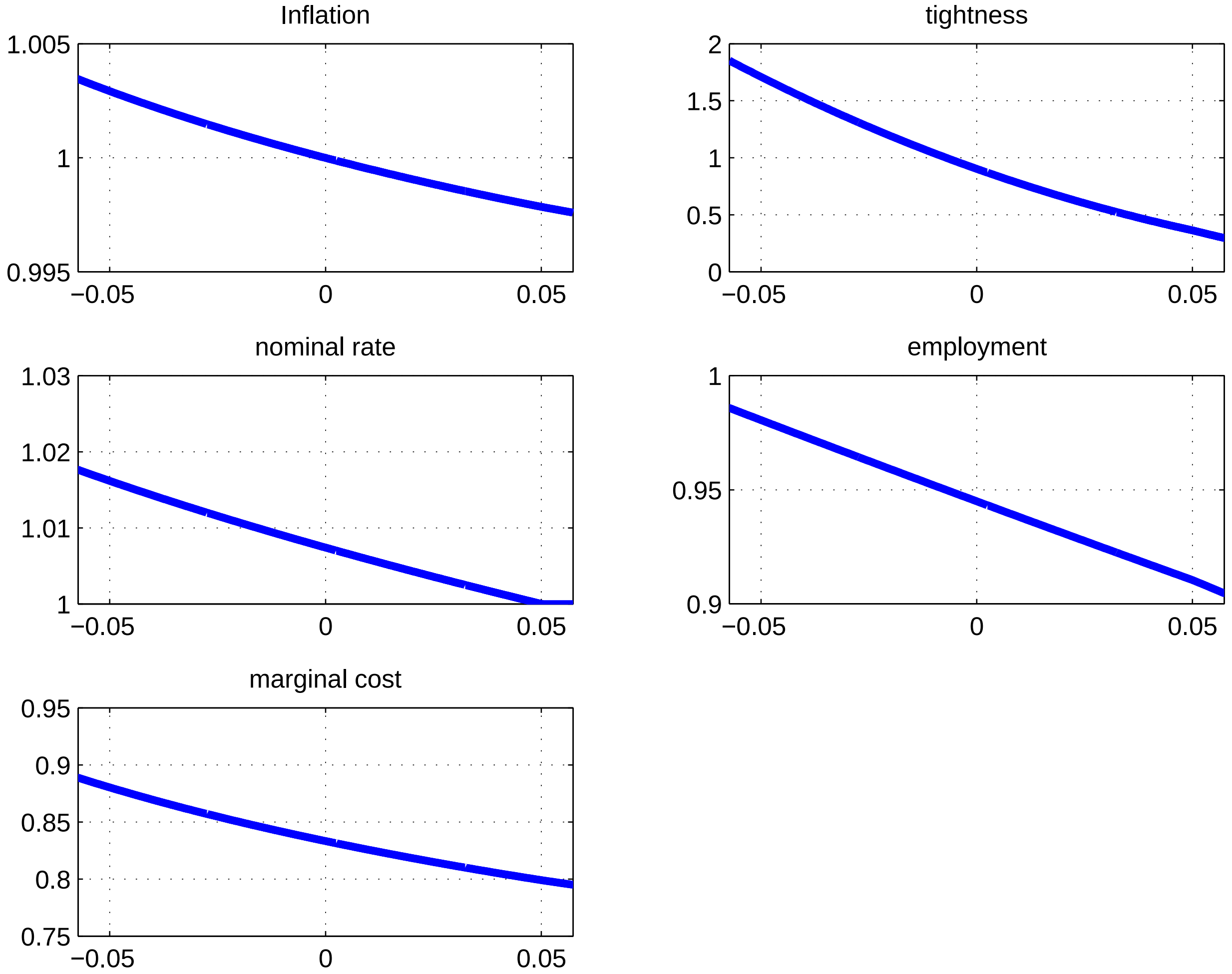
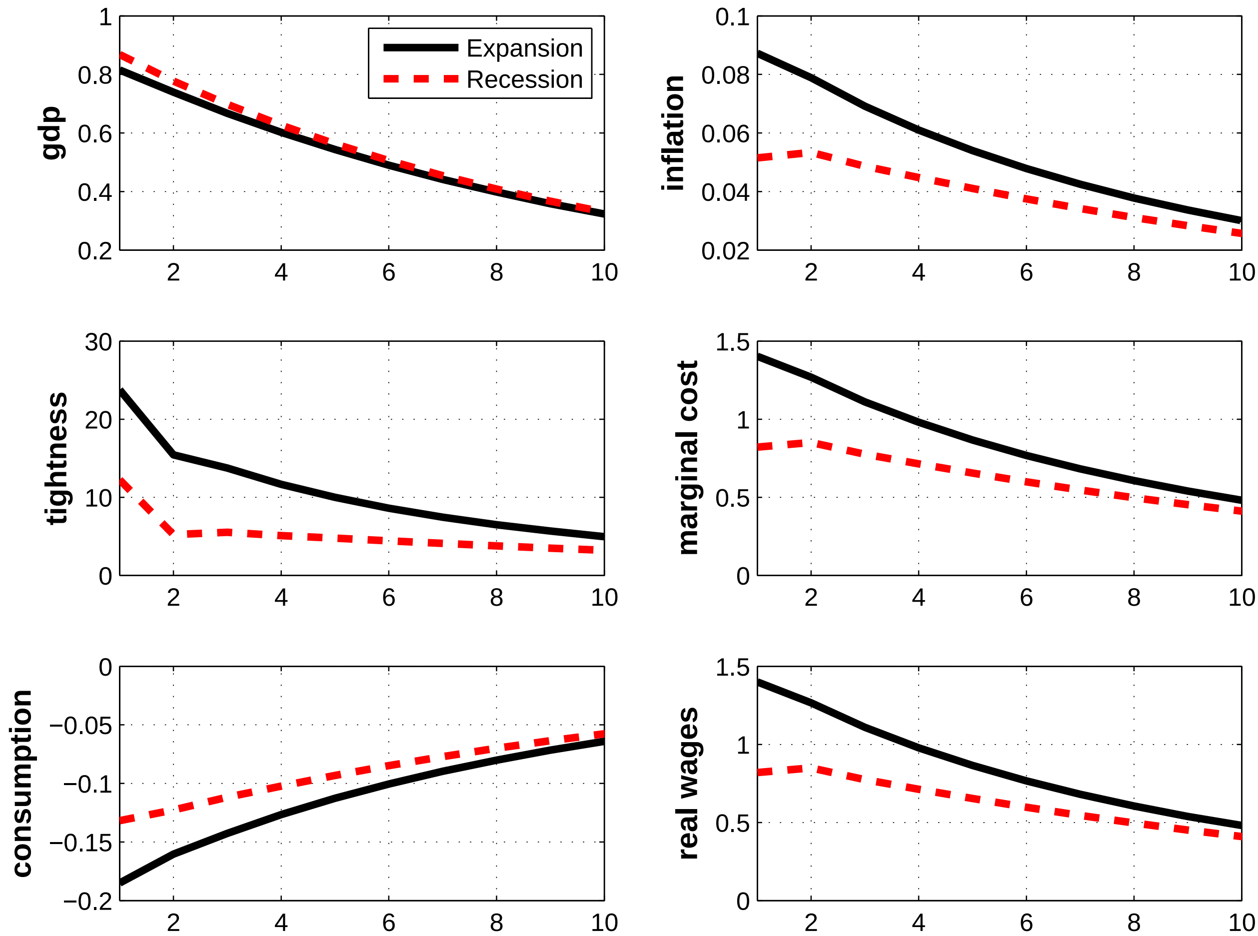
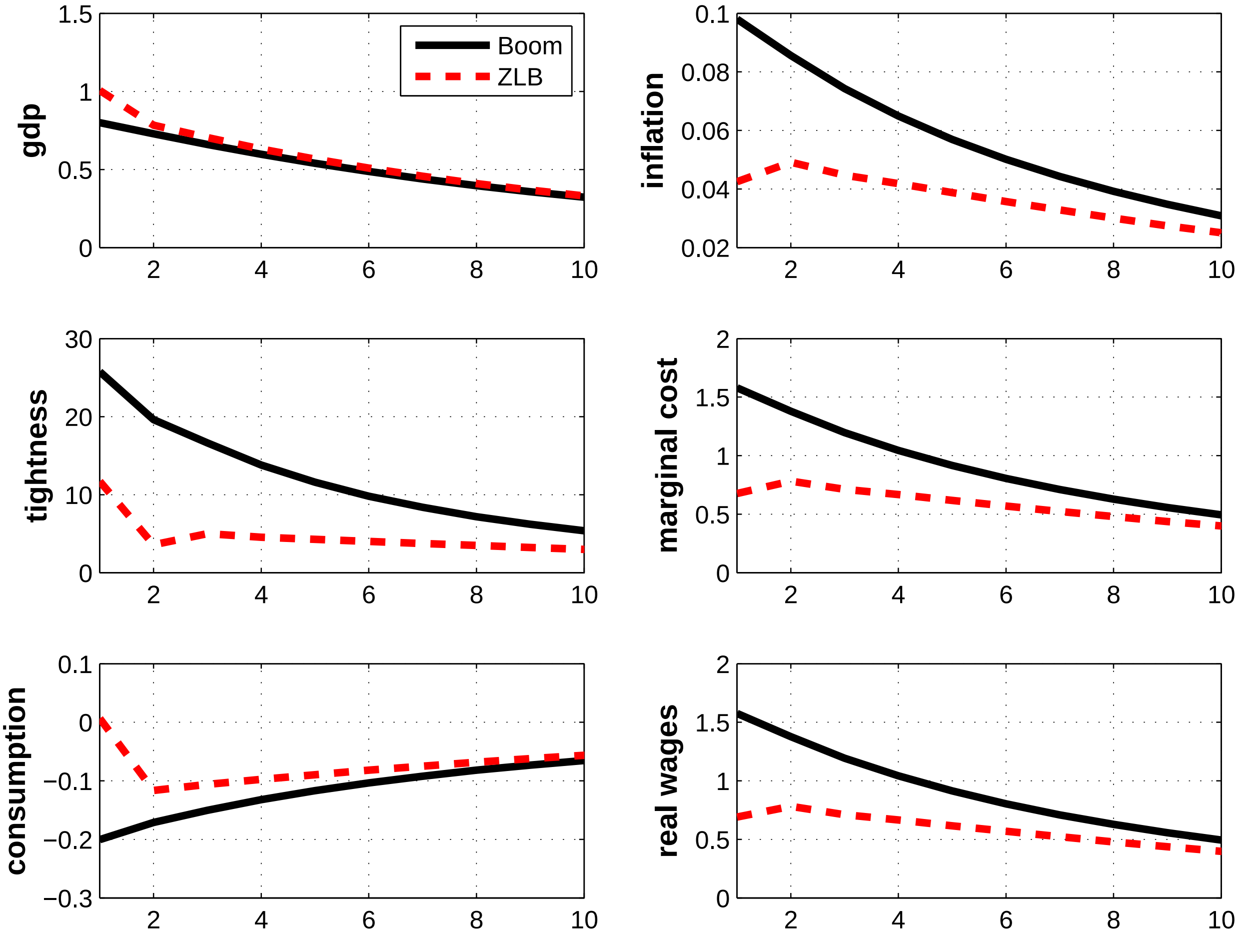


Figure 17: Multipliers effects of Government Spending in Boom and Recession, Model with Credible Bargaining.



Notes: The black line represents the difference between the path of GDP/inflation with i) only a positive preference shock and ii) a preference and government spending shock. This difference is then scaled by the initial increase in government spending, so that the response is the multiplier effect of government spending. The red dashed line represents the same but with a negative preference shock.

Figure 18: Multipliers effects of Government Spending in Boom and ZLB, Model with Credible Bargaining.



Notes: The black line represents the difference between the path of GDP/inflation with i) only a positive preference shock and ii) a preference and government spending shock. This difference is then scaled by the initial increase in government spending, so that the response is the multiplier effect of government spending. The red dashed line represents the same but with a negative preference shock.