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JEL Classification

E31, E32, E62, F31, F41

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I. Introduction

Are government spending shocks inflationary? Despite the rapid progress in identifying exogenous shocks to government spending and understanding their macroeconomic effects (e.g., Blanchard and Perotti, 2002; Mountford and Uhlig, 2009; Ramey, 2011), the literature has not reached a consensus on this matter. For example, Jørgensen and Ravn's (2022) recent review noted that almost equal numbers of studies have found disinflationary (or deflationary), inflationary, and null (i.e., insignificant) responses to government spending shocks.[1] These findings seem puzzling because conventional wisdom is that increases in government spending are inflationary via the positive aggregate demand effect.

Understanding the effect of government spending shocks on inflation has become particularly important since the Great Recession, as the size of the fiscal multiplier hinges on the ability of higher government spending to drive up inflation and therefore reduce the real interest rate when the nominal interest rate is at the zero lower bound (ZLB) (e.g., Christiano et al., 2011; Eggertsson, 2011; Woodford, 2011).[2] However, related research has been greatly constrained in this context because only a handful of low-frequency (i.e., quarterly) observations are available when the economy is at the ZLB (2009–2015). Although alternative approaches have been adopted to resolve

[1] For example, Edelberg et al. (1999), Caldara and Kamps (2008), Ben Zeev and Pappa (2017), Mumtaz and Theodoridis (2020), and Ferrara et al. (2021) found an inflationary response to a government spending shock, whereas Fatás and Mihov (2001), Mountford and Uhlig (2009), Dupor and Li (2015), Ricco et al. (2016), d'Alessandro et al. (2019), Jørgensen and Ravn (2022), and Hall and Tahpar (forthcoming) found a disinflationary or deflationary response to the same shock. See Jørgensen and Ravn (2022) for a comprehensive review of empirical studies on price (or inflation) response to government spending shocks.

[2] Under nominal rigidities, an upward shift in expected real wage path following fiscal expansion leads businesses to increase prices today, resulting in higher inflation, which reduces the real interest rate; such a reduction also leads households to shift consumption toward the present, increasing the size of the fiscal multiplier. This effect is particularly strong when monetary policy is not responsive due to the ZLB.

this constraint, limited time-series observations do not provide sufficient statistical power to obtain a definite answer to the question.[3]

We circumvent this challenge in identifying a causal relationship between government spending and inflation by exploiting high-frequency (daily) data for both U.S. defense spending (announcement and actual payments), constructed by Auerbach and Gorodnichenko (2016), and the online price index (OPI), constructed by Cavallo and Rigobon (2016). To the best of our knowledge, this is the first attempt to identify the effect of government spending shocks on inflation using high-frequency data, which are largely immune to the potential misspecification problem in Vector Autoregressions (VARs) when imposing timing restrictions on low-frequency data.[4]

As emphasized by Ramey (2016), timing assumptions are more plausible, and shocks are less likely to be anticipated in high-frequency data than shocks identified in data analyzed at the quarterly frequency. Moreover, using daily-frequency spending proxies alleviates the concern raised in Brunet (2020) about using the National Income Product Accounts (NIPA) to measure government spending.[5] The fact that the daily index is constructed using online prices can help identify the short-run effects of government spending on prices because prices change more frequently in online markets than in traditional brick-and-mortar stores (Gorodnichenko et al., 2018).

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[3] To circumvent the lack of sufficient time-series data to study the effect of government spending shocks at the ZLB, some authors have used the time-varying parameter model (Klein and Linnemann, 2019), relied on historical samples covering more than 100 years (Ramey and Zubairy, 2018), or focused on a particular country (Japan), where the chronic ZLB since the 1990s provides a sufficient number of observations to make statistical inferences (Miyamoto et al., 2018).

[4] An alternative approach is to use inflation expectations extracted from financial market data, readily available at high frequency. However, as explained in Gürkaynak et al. (2010), this so-called "break-even" inflation measure can be affected by an inflation risk premium or liquidity premium, resulting in a distorted measure of inflation expectations. Such distortion is magnified when using higher frequency data, especially for our sample, which includes a period of financial turmoil. We still use a break-even inflation measure for robustness checks.

[5] Brunet (2020) argues that NIPA measures government spending too late in the process, which is problematic when measuring the influence of government spending on economic activity. While a significant fraction of government payments are often delayed until final goods are delivered to the government, firms hire workers and purchase materials in advance of such payments. Thus, government spending may be recorded in NIPA after its direct effects on the economy have already begun and sometimes after the direct effects have concluded.

We estimate the effect of government spending shocks at the ZLB using local projections, as in Jordà (2005) and Auerbach and Gorodnichenko (2016). Importantly, we find robust evidence that prices decline significantly after a positive government spending shock. The decline in the price level is robust to controlling for macroeconomic news announcements and the Fed's announcements about quantitative easing. This finding is also robust to considering the open economy property of the U.S. economy (i.e., controlling for the nominal exchange rate and oil prices) and controlling for other distinct features of the U.S. economy at the ZLB at a daily frequency, such as heightened policy uncertainty and consumer pessimism.

We find that inflation expectations over the medium to long term—measured by daily financial market data—also decline mildly in response to government spending shocks. Therefore, both ex-ante and ex-post real interest rates increase after positive government spending shocks, suggesting that the (expected) inflation channel of government spending may not work at the ZLB despite the theoretical appeal of this idea. Indeed, by employing the Aruoba-Diebold-Scotti Business Conditions Index (ADS Index) constructed by Aruoba et al. (2009), which provides a proxy of daily economic conditions, we find that government spending shocks fail to enhance economic activity at the ZLB.

When we incorporate additional data from outside the ZLB period (i.e., normal times), we find that an identical shock can become inflationary, which is in sharp contrast to the case of the ZLB. From a theoretical perspective, it is even more puzzling that the inflationary response is stronger when the ZLB no longer constrains the economy. This is because we expect a less inflationary response when active monetary policy (i.e., Taylor rule) is allowed, translating into an increase in the real interest rate and a stronger crowding-out effect compared to the ZLB. To the extent that the high-frequency data used in this study provide more reliable identification of a government spending shock than data from existing studies using quarterly variables, our empirical findings contribute to understanding the so-called "fiscal price puzzle" examined by Jørgensen and Ravn (2022).

Although our findings are in sharp contrast to predictions of standard New Keynesian models, they can be reconciled with the results from the recent theoretical study by Abo-Zaid and Kamara (2020), who in their two-agent New Keynesian (TANK) model show that credit constraints weaken the inflation channel of government spending shocks at the ZLB. In practice, tighter credit constraints following the collapse of the U.S. housing market overlapped with the binding of the ZLB constraint, which confounded the effect of government spending on prices. We confirm that defense spending shocks during the ZLB are indeed more deflationary when household credit constraints tighten. In Section IV, we further discuss details of the theoretical model and explain how we used our data to test the theoretical predictions of the credit constraint channel.

Given the lack of major military events during the period of study, there remain concerns about the economic significance of defense spending in our ZLB sample. It is possible that daily variation in defense spending is too small to exercise a meaningful aggregate demand effect. We thus conducted an event study analysis similar to that of Dupor and Li (2015) by using news about massive future government spending (the American Recovery and Reinvestment Act). We still observed that important fiscal news failed to generate inflation between 2008 and 2009, during which households faced tighter credit constraints. This finding corroborates the implications of credit constraints on the inflation channel of government spending.

Overall, our findings suggest that the stimulating effect of fiscal expansion in the U.S. economy during the recent ZLB episode was unlikely to operate via the inflation channel. Thus, using a similar methodology, we provide a potential explanation for the important finding in Ramey and Zubairy (2018) that the government spending multiplier is not systematically larger at the ZLB than during normal times, especially when a military news shock is employed to identify exogenous changes in government spending. However, it should be understood that our findings do not dispute the theoretical appeal of the idea of an inflation channel of government spending. We simply show that this channel was absent in the recent data and claim that tighter credit constraints likely played a crucial role.

The remainder of the paper is organized as follows. Section II uses a simplified New Keynesian model to illustrate the effect of a government spending shock on inflation at the ZLB, introduces novel daily data on the key variables—including government spending and the price index—, and explains the econometric model. Section III presents the main findings and provides a series of robustness checks and additional exercises using observations from normal times. Section IV discusses how the empirical findings can be potentially reconciled with recently developed theoretical models, then uses our data to test the prediction of the credit constraint channel. Section V concludes.

II. EMPIRICAL FRAMEWORK

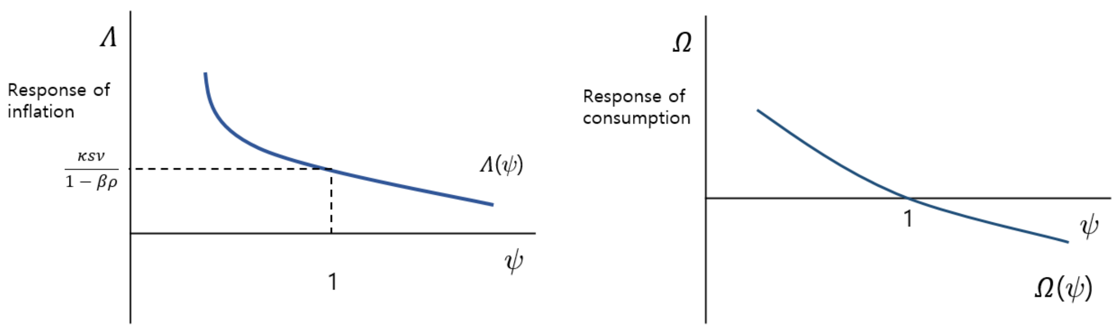
A. Theoretical arguments

Using a simple theoretical framework following Dupor and Li (2015), we illustrate how the binding ZLB constraint strengthens the inflationary response to government spending shocks, further stimulating consumption and output compared to normal times. Appendix A summarizes the details of the model; we present only the key theoretical predictions about the interaction between the ZLB and inflation (and consumption) in the main text. At the ZLB, the monetary authority keeps the nominal interest rate at zero regardless of inflation. Though simplified, the ensuing mechanism, generating a higher multiplier via an increase in (expected) inflation, is shared by theoretical models that explicitly consider the ZLB (e.g., Christiano et al., 2011; Eggertsson, 2011; Woodford, 2011).

Figure 1, taken from Dupor and Li (2015), plots the equilibrium impact responses of inflation and consumption to a government spending shock, depending on the value of the weight on inflation ψ in the standard Taylor rule. The other parameters of the model are explained in Appendix A.

In sum, the inflationary response to government spending shocks is maximized at the ZLB, in which the short-term monetary policy rate is not responsive to inflation (i.e., $\psi \to \infty$). The ZLB also maximizes the size of the fiscal multiplier by reducing the real interest rate. This simple theoretical illustration clarifies the crucial role of inflation in the transmission channel of government spending at the ZLB. Equipped with a novel dataset spanning the ZLB at a daily frequency, we now have the exogeneity of fiscal policy and enough statistical power to test the empirical relevance of this theoretical prediction.

Figure 1. Equilibrium impact responses of inflation and consumption to government spending shock



Note: This graph plots the equilibrium impact responses of inflation (left) and consumption (right) to a government spending shock in terms of the parameter ψ, denoting the weight of inflation in the standard Taylor rule.

B. Local projection method

We briefly describe the main empirical framework used in the analysis. We employ Jordà's (2005) methodology for estimating the responses of various macroeconomic and financial variables to government spending shocks. The local projection method, by imposing weaker assumptions on the dynamics of the data, allows for more flexible estimation of impulse response functions (IRFs) and, therefore, has been widely adopted in empirical studies. It is particularly suitable for a high-frequency analysis such as ours because it does not suffer from the curse of dimensionality inherent to VARs. For example, our baseline model requires estimating 20 lags of each variable, and the IRF horizon reaches 120 periods (six months). Such dimensions are far beyond what is typically considered in VARs for estimating the effects of fiscal policy.

We iteratively estimate the following regression to calculate Jordà's impulse response function:

$$y_{t+h} - y_{t-1} = \alpha_h + \beta_h shock_t + \Phi_h(L) X_t + \varepsilon_{t+h}, \ \ for \ h = 0, 1, 2, \cdots, \tag{1}$$

where y_t is the dependent variable; $shock_t$ is the daily government spending shock; $\Phi_h(L)$ is a lag polynomial; and X_t is a set of control variables. We always include the lags of the dependent variable, the shock variable, and a proxy for economic conditions (i.e., the ADS Index) in X_t to deal with any possible serial correlation of variables and the omitted variable bias (Montiel Olea and Plagborg-Møller, 2021).

These specifications also correspond to the standard VAR approach in identifying a government spending shock (Blanchard and Perotti, 2002), in which government spending appears before other macroeconomic variables in the Cholesky decomposition. This order reflects the identifying assumption that the measure of government spending $shock_t$ does not respond contemporaneously to innovations in y_t. Given that we address $shock_t$ at a daily frequency, this assumption is more likely to hold than was assumed in Blanchard and Perotti (2002). Following Auerbach and Gorodnichencko (2016), who used the same shock variable, we include 20 lags of every variable in X_t.

In Equation (1), β_h shows the response of the dependent variable h days after the shock. Therefore, a series of values of β_h illustrates the dependent variable's impulse response function to a shock. In our analysis, β_h indicates the cumulative impact of military spending changes on the dependent variable after h days. One potential problem in Jordà's method is the serial correlation of the error terms; in our case, a potential problem is the extent of persistence of the dependent variable. To address these challenges, we adopt Newey-West (1987) heteroskedasticity and autocorrelation-corrected standard errors.

State-dependent local projections. While our baseline analysis, due to the availability of daily data, focuses on the period characterized by the binding ZLB constraint, we extend our analysis to compare the ZLB period with normal times by (i) incorporating extended data on the second measure of daily government spending (i.e., payments to defense contractors) and (ii) performing the analysis at a monthly frequency for a longer period using the consumer price index (CPI). Local projections are particularly useful in this context, as the above linear model can be conveniently transformed into a state-dependent model, which allows for testing, within a single equation framework, of whether the effects of government spending shocks differ between normal times and the ZLB period.

Compared to the subsample analysis, this method facilitates more efficient estimation by increasing the effective sample size; it has been used in many studies on the ZLB (see, for similar applications, Auerbach and Gorodnichenko, 2016; Ramey and Zubairy, 2018; Miyamoto et al., 2018; Choi and Yoon, forthcoming). We closely follow the state-dependent local projection model used by Auerbach and Gorodnichenko (2016) and Ramey and Zubairy (2018). Therefore, the nonlinear version of the regression model can be specified as follows:

$$\begin{aligned} y_{t+h} - y_{t-1} = I_{t-1}\big[\alpha_{Z,h} + \beta_{Z,h} shock_t + \mathit{\Phi}_{Z,h}(L)X_t\big] + \\ (1 - I_{t-1})\big[\alpha_{N,h} + \beta_{N,h} shock_t + \Phi_{N,h}(L)X_t\big] + \varepsilon_{t+h}. \end{aligned} \quad (2)$$

Here, to acquire a state-dependent impulse response function, we allow a variation in the coefficients according to whether the ZLB is binding. Specifically, the first part of Equation (2) accounts for the binding ZLB, and the second part corresponds to the period without the ZLB, where I_t is a binary indicator denoting whether the economy falls in the ZLB period. Thus, the series $\beta_{Z,h}$ for $h = 1, 2, \ldots$ denotes the impulse response to government spending shocks at the ZLB, whereas the series $\beta_{N,h}$ describes the same during normal times.

C. Data

This section presents the five datasets available at daily frequency: defense spending, price index series, economic activity index, consumer confidence index, and uncertainty index. As these data are not often employed in empirical studies at this frequency, we will provide some explanation of how they are constructed at a daily frequency.

First, we use two daily government defense spending series constructed by Auerbach and Gorodnichenko (2016). The first series is the announced volume of contracts awarded daily by the U.S. Department of Defense (DoD). As modifications to existing contracts are anticipated, the series extracts information on the announcement of new contracts only—first-time contracts—on the DoD website. The second series is payments to defense contractors, reported in the daily statements of the U.S. Treasury.

Using defense spending as a representative for government spending is justifiable for several reasons. Compared to other types of spending, defense spending (i) is less likely to be determined by current economic conditions, (ii) is much less predictable than other types of payments and is a major source of variation in government spending, (iii) has a large domestic component, and (iv) obviates the concern that substitutability between private and government consumption drives our results. Auerbach and Gorodnichenko (2016) confirm the validity of these measures by showing that (i) announced volumes of contracts are closely related to major military developments and (ii) the payment series closely tracks the standard government spending data available at a quarterly frequency.

Following Auerbach and Gorodnichenko (2016), we use the novel framework introduced by De Livera et al. (2011) to deseasonalize and detrend both series. This method allows for trends and multiple seasonal components to be modeled as a parsimonious series of trigonometric functions, thereby alleviating any existing seasonal variation and other predictable components. Auerbach and Gorodnichenko (2016) asserted that using these two series helps underscore the key role of fiscal foresight in timing government spending shocks and their responses. We also extend the second series—payments to defense contractors—until 2018 to investigate the inflation response to government spending shocks after the ZLB is lifted.

Figure B.1 in Appendix B plots the raw data of both series at a daily frequency. The daily average values of the two series (in million USD) are 778.80 and 1,356.74; their standard deviations are 1,747.43 and 424.20. This indicates a substantial variation in both measures over time, which helps identify a causal relationship between defense spending and inflation. Moreover, changes in these defense spending series are not simply balanced by the other component of government spending, further validating our choice of daily defense spending as a shock to government spending. Figure B.2 plots the ratio of the two series to the value of overall government spending after summing up daily defense spending to the quarterly level. We still observe significant variation over time.

Second, we obtain the daily OPI from Cavallo and Rigobon (2016); OPI is calculated using price data from numerous websites. While Cavallo and Rigobon (2016) mimic the construction of the conventional price index, the price index is updated daily by replacing the usual data collection process with an automated "web-scraping" program. Therefore, this index is conceptually consistent with the CPI and closely tracks fluctuations in the CPI during the sample period at a daily frequency (see Figure B.3). Moreover, new and disappearing products are easily detected and reflected in the index because the collected data are comprehensive. However, the daily OPI is available only from July 2008, which is chosen as the starting point of our empirical analysis.

Third, we use the ADS index from Aruoba et al. (2009). The ADS Index tracks real business conditions at high observation frequency (i.e., daily) and fully covers our sample period (see Figure B.4). Its underlying economic indicators combine high- and low-frequency data (e.g., weekly initial jobless claims, monthly payroll employment, etc.). Our baseline specification includes the ADS Index as a daily proxy for overall economic conditions, eliminating any remaining concern about endogeneity in daily defense spending.

Lastly, we use a daily measure of consumer confidence and economic policy uncertainty to shed further light on the transmission of government spending shocks. For consumer confidence, we use the Gallup Economic Confidence Index (ECI), which is based on questions from Gallup's U.S.

Daily Survey Poll about national economic conditions, posed daily to approximately 500 respondents between January 2008 and December 2017. This index is calculated by adding the percentage of respondents who rate current economic conditions ((‘Excellent’ + ‘Good’) – ‘Poor’) to the percentage who say the economy is (‘Getting better’ – ‘Getting worse’) and dividing the sum by 2. Weighting adjustments are used for aggregation to make the index representative of the U.S. population. See Lewis et al. (2019) for a detailed description of this index and a discussion of its sensitivity to various macroeconomic news.

For economic policy uncertainty, we use the daily news-based Economic Policy Uncertainty (EPU) Index drawn from Baker et al. (2016), which is based on newspaper archives from the Access World News (NewsBank) service. The primary measure for this index is the number of news articles in the U.S. that contain at least one term from each of the three sets of terms: (i) ‘economic’ or ‘economy’; (ii) ‘uncertain’ or ‘uncertainty’; (iii) ‘legislation,’ ‘deficit,’ ‘regulation,’ ‘congress,’ ‘federal reserve,’ or ‘white house.’ Both series are plotted in Figure B.5. To reduce excessive volatility at daily frequency, we plot the three-day moving average of the daily index.

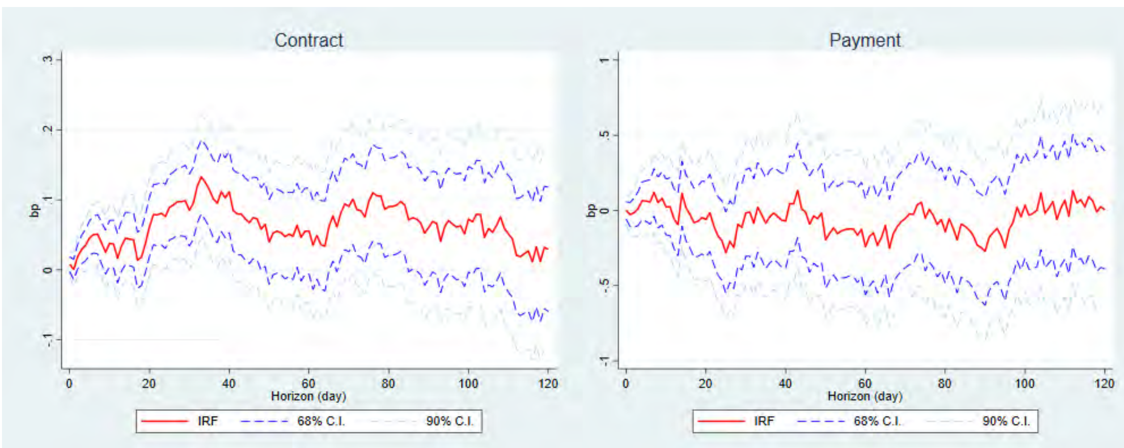
Other daily-frequency variables used in the analysis are standard in the literature, including the trade-weighted (i.e., effective) nominal exchange rate, nominal interest rates at different maturities, and real interest rates at different maturities measured by yields on Treasury Inflation-Protected Securities (TIPS). We also analyze the response of inflation expectations, measured by the difference between the nominal treasury yields and TIPS yields at the corresponding maturities (i.e., break-even inflation). We use the Treasury yields with five (twenty)-years maturity for the medium (long)-term interest rates. These variables are plotted in Figure B.6.

III. EMPIRICAL FINDINGS

A. Main results

Response of nominal exchange rate. As a first pass, we check whether the main finding of Auerbach and Gorodnichencko (2016) still holds in our subsample at the ZLB. We plot the response of the nominal effective exchange rate to a unit shock to the DoD announcements (daily log volume of awarded contracts, deseasonalized and detrended). Given the relatively short sample in our analysis compared to Auerbach and Gorodnichencko's (2016), we report both 68% and 90% confidence bands. The baseline analysis is from December 1, 2008, to March 28, 2014. Although the ZLB persisted until December 2015, the ending period is constrained by the availability of daily government spending data.

Figure 2. Nominal exchange rate response to government spending shocks



Note: This figure shows the impulse response of the nominal effective exchange rate, using the trade-weighted exchange rate of the dollar. An increase denotes appreciation of the dollar vis-à-vis its trading partners. The left panel shows the response to a unit shock to DoD contracts; the right panel shows the response to a unit shock to treasury payments. The dashed lines denote 68% and 90% confidence intervals. The estimation sample is from December 1, 2008, to March 28, 2014.

As shown in the left panel of Figure 2, about 30 business days after the announced spending, the dollar appreciates by 0.12 basis points, largely consistent with the original finding of Auerbach and Gorodnichencko (2016), who used data between 1994 and 2014. Additionally, in the right panel, we present the daily responses of the exchange rate to a unit shock to actual spending (daily payments to defense contractors) to demonstrate the difference between announced and actual spending shocks. Consistent with Auerbach and Gorodnichenko (2016), the nominal exchange rate, a forward-looking asset price variable, responds only to the news shock in defense spending.

While these findings do not align with those of empirical studies reporting nominal depreciation in response to fiscal expansion in advanced economies (e.g., Ravn et al., 2012; Ilzetzki et al., 2013; Kim, 2015; Miyamoto et al., 2019), they are in line with the prediction of standard open economy models, such as the Mundell–Fleming model and more recent DSGE models (e.g., Erceg et al., 2010). As high-frequency data alleviate concerns about identification when fast-moving financial variables such as the exchange rate are involved, we view the nominal appreciation following fiscal expansion news as a credible description of the U.S. economy during the recent ZLB period.

Response of prices. Figure 3 summarizes the main finding of this study: the responses of the daily log OPI to government spending shocks during the ZLB. Prices decline persistently and statistically significantly after fiscal expansion, regardless of whether government spending shocks are identified by announcements (Panel A) or actual payments (Panel B).[6] The effects are also economically meaningful. Six months later (i.e., after 120 business days), prices fall by -0.03 basis points in response to the unit announcement shock and by -0.09 basis points in response to the unit payment shock.[7] Although these effects seem minuscule at first glance, their magnitude translates into a -0.04 (-0.11) percent decline for the contract announcement (actual payment) shock when the shock

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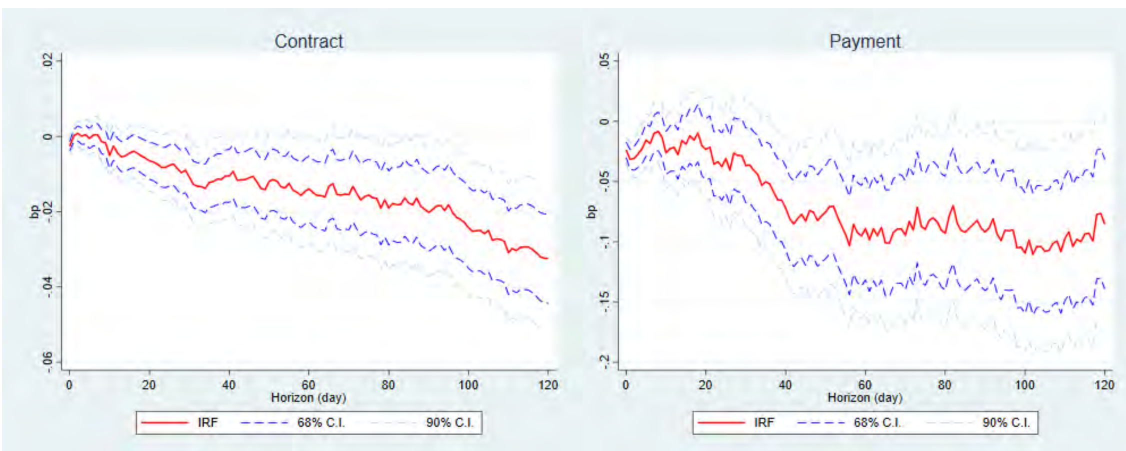
[6] In Figure C.1 in Appendix C, we present the response of daily prices to government spending shocks without controlling for the daily economic activity index. The results are similar to those in Figure 3, confirming the assumed exogeneity of daily defense spending to economic conditions at such a high frequency.

[7] By extending the forecasting horizon up to one year (i.e., 250 days), we confirm that the maximum decline occurs at this horizon (six months). The temporary effect on prices is not surprising given the transitory nature of daily government spending shocks.

is scaled to one percent of the GDP, which is a standard normalization in studies on government spending.[8]

Given that the daily frequency of our analysis of covers only the ZLB period, it is not possible to compute the longer-horizon impulse response functions (for example, up to 40 quarters), often considered in VAR studies, making it difficult to directly compare the economic significance of our findings with those of existing studies that use low-frequency data. Nevertheless, the economic magnitude of the short-run price decline is similar to the estimates of Fatás and Mihov (2001) and Jørgensen and Ravn (2022), who document in their baseline VAR model an approximately -0.1 percent decline in the price index four quarters after an identical size government spending shock (one percent of the GDP).

Figure 3. Price response to government spending shocks



Note: This figure shows the impulse response of the price level using the daily online price index. The left panel shows the response to a unit shock to DoD contracts; the right panel shows the response to a unit shock to treasury payments. The dashed lines denote 68% and 90% confidence intervals. The estimation sample is from December 1, 2008, to March 28, 2014.

[8] We follow Auerbach and Gorodnichenko (2016) in converting the coefficients into a relevant context. Our shock is measured as a percentage deviation from the daily average of awarded contracts and vendor payments. As there are roughly 250 business days for any given year, we scale the coefficients by multiplying by 250. We then divide the coefficients by two because the annual defense contract budget is roughly two percent of the U.S. GDP as of 2013. The resulting changes in prices after a defense spending shock corresponding to one percent of the GDP are, therefore, -0.04% ($= -0.0003 \times 250 \times 0.5$) and -0.11% ($= -0.0009 \times 250 \times 0.5$), respectively.

The deflationary responses to government spending shocks shown in Figure 3 identified via the newly constructed daily data during the ZLB contribute to the literature on the fiscal price puzzle. Despite the straightforward theoretical prediction of the standard New Keynesian model, empirical studies have often found contrasting evidence about the sign of the effect of government spending shocks on inflation or prices, as summarized in Table 1. However, most of these studies focus on pre-ZLB periods. To the extent that high-frequency data alleviate the endogeneity issue in identifying a causal relationship between macroeconomic variables, our novel findings obtained using daily data provide a credible description of the effects of fiscal shocks at the ZLB. In the next section, we shed further light on our findings by comparing the responses of prices to government spending shocks between the ZLB and normal times.

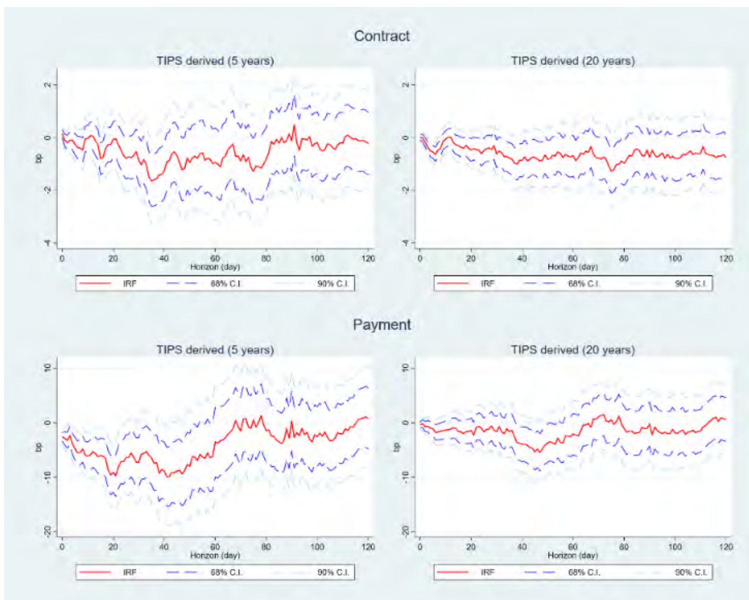
Table 1. Existing results on effects of government spending shocks on prices and inflation

Authors	Main sample	Subsample stability	ZLB
Inflationary response			
Edelberg et al. (1999)	1948Q1-1996Q1		No
Caldara and Kamps (2008)	1955Q1-2006Q4		No
Ben Zeev and Pappa (2017)	1947Q1-2007Q4		No
Mumtaz and Theodoridis (2020)	1955Q1-2015Q4	Inflationary (1980Q1-2015Q4), but disinflationary (1955Q1-1979Q4)	No
Ferrarra et al. (2021)	1964Q1-2015Q4	Disinflationary (1964Q1-1997Q4)	No
Deflationary or disinflationary response			
Fatas and Mihov (2001)	1960Q1-1996Q4		No
Mountford and Uhlig (2009)	1955Q1-2000Q4		No
Dupor and Li (2015)	1959M1-2002M6	Disinflationary (1981M10-2002M6), but insignificant (1959M1-1979M12)	No
D'Alessandro et al. (2019)	1954Q3-2007Q4		No
Jørgensen and Ravn (2022)	1966Q4-2008Q3	Disinflationary (1966Q4-2008Q3 or 1966Q4-2019Q4), but insignificant (1984Q1-2008Q3). Substantially more deflationary once the ZLB period is added.	Yes
Hall and Thapar (forthcoming)	1968Q1-2011Q4		No

Note: This table summarizes the signs of price (or inflation) responses to government spending shocks in other studies. The last column (ZLB) shows whether the study includes explicit consideration of ZLB periods.

Response of inflation expectations. Despite the strong evidence presented in Figure 3, it is still possible that fiscal expansion increases future expected inflation without increasing current inflation. To the extent that consumption and investment decisions are affected by both the current and expected real interest rate, investigating the response of inflation expectations has its merits. Figure 4 plots the responses of inflation expectations inferred from financial market data (i.e., the difference between nominal Treasury yields and TIPS yields for the same maturity) at two different horizons (five and twenty years ahead).

Figure 4. Inflation expectation response to government spending shocks



Note: This figure shows the impulse response of the inflation expectation derived by subtracting TIPS yields with a maturity of 5 years (left) and 20 years (right) from treasury yields of corresponding maturities. The upper panel shows the response to a unit shock to DoD contracts; the lower panel shows the response to a unit shock to treasury payments. The dashed lines denote 68% and 90% confidence intervals. The estimation sample is from December 1, 2008, to March 28, 2014.

The left panel corresponds to the five-year-ahead break-even inflation and the right panel to the twenty-year-ahead break-even inflation. Although the results are less clear-cut than in the OPI case, they suggest a mild decline in inflation expectations, especially for the five-year-ahead period. The finding of a weaker long-term response is consistent with the notion that long-term inflation expectations were still anchored at the ZLB (Ascari and Sbordone, 2014; Choi et al., 2022). However, caution is required when interpreting these results because variation in TIPS yields can be affected by the inflation risk premium or liquidity premium, apart from inflation expectations of financial market participants (Gürkaynak et al., 2010), and the bias can be substantial (Fleckenstein et al., 2014).[9] This explains why we prefer the actual inflation response using the OPI because it is free of such confounding factors.

Response of real interest rates. While the U.S. economy falls into the binding ZLB state during the sample period, this binding state holds only in the absolute sense. The response of the nominal interest rate, which is conditional on other structural shocks, including government spending shocks, might not be entirely null in the econometric model. This is especially true in the case of the long-term interest rate: a deflationary response conditional on government spending shocks may not necessarily translate into a rise in the real interest rate even at the ZLB. To guard against this possibility, we investigate three types of real interest rates: (i) the difference between the effective Federal Funds rate and actual annualized inflation using the OPI, (ii) five-year TIPS yields, and (iii) twenty-year TIPS yields. However, caution is still required in interpreting the results because of the inflation risk premium or liquidity premium in TIPS.

The first column of Figure C.2 in Appendix C shows that the response of the realized interest rate is generally positive, especially toward the end of the forecasting horizon. This is not surprising given the strong deflationary effect three months after the shock, shown in Figure 3, and the absence of fluctuations in the nominal policy rate at the ZLB. The second and third columns report the response of the ex-ante real interest rate implied from the TIPS yields. The responses are statistically insignificant in general. However, we observe no decline in the real interest rate, as predicted by standard New Keynesian models, regardless of how the real interest rate is measured.

Response of economic activity. The lack of inflationary response (Figures 3 and 4) and, therefore, the lack of a decline in the real interest rate (Figure C.2), suggest that government spending shocks

[9] However, the direction of bias created from inflation risk premium or liquidity premium is theoretically unclear.

at the ZLB may not be strongly expansionary, in contrast to the standard prediction in the theoretical literature (Christiano et al., 2011; Eggertsson, 2011; Woodford, 2011). We indirectly test this hypothesis by employing the ADS index as a new dependent variable. Figure C.3 confirms that defense spending shocks fail to expand economic activity when the economy is at the ZLB. Together with the deflationary response shown in Figure 3, this finding casts doubt on the well-known theoretical prediction that government spending shocks are more expansionary at the ZLB than during normal times via the inflation channel (e.g., Christiano et al., 2011; Eggertsson, 2011; Woodford, 2011). Nevertheless, a more direct measure of consumption at a daily frequency is required to draw a definite conclusion about the size of the government spending multiplier.[10]

B. Robustness checks

In this section, we provide a battery of robustness tests for the paper's main finding of a deflationary effect of government spending shocks at the ZLB. To save space, the corresponding graphs are displayed in Appendix C.

Estimating smooth local projections. Despite the flexible nature of the local projection method compared to VARs, its nonparametric nature comes at an efficiency cost, and it often displays excessive variability in estimated IRFs (Ramey, 2016). Thus, we test the robustness of our key finding using the smooth local projection (SLP) method, recently proposed by Barnichon and Brownless (2019). They model the sequence of impulse response coefficients as a linear combination of B-spline basis functions and then estimate the coefficients of this linear combination using a shrinkage estimator that shrinks the IRFs toward a polynomial.[11] The key advantage of SLP is an increase in the estimation accuracy of local projections while preserving flexibility. Figure C.4

[10] Because the ADS index is constructed from a variety of stock and flow data capturing different dimensions of economic conditions and different frequencies (daily term premium, weekly initial jobless claims, monthly employment, and quarterly GDP), it does not directly correspond to consumption or output in the theoretical model. While this index controls for contemporaneous economic conditions when identifying the effect of defense spending on prices, its estimated nature poses some challenges in its use in inferring the size of the government spending multiplier.

[11] We use the Matlab code provided by Barnichon and Brownless (2019) to compute the SLP IRFs. For further details, see Barnichon and Brownless (2019).

presents the results obtained using SLP. As expected, the IRFs become less volatile when we increase the smoothness parameter, but the deflationary effect and its persistence are preserved.

Controlling for macroeconomic news and the Fed's monetary policy decisions. While we have controlled for daily economic conditions—proxied by the ADS index—to alleviate concern about omitted variable bias, it may not be enough to isolate the effect of government spending shocks from other confounding factors when using high-frequency data. Following Auerbach and Gorodnichenko (2016), we further control for macroeconomic news announcements and the Fed's announcements about quantitative easing at the daily frequency. Controlling for the latter is particularly important given our focus on the ZLB period.

Following Swanson and Williams (2014) and Datta et al. (2021), we compute the surprise component of macroeconomic news releases using the difference between the released figures and the financial market expectations from Bloomberg Financial Services. The current and lagged values of the surprise component in the following variables are additionally controlled: the capital utilization rate, consumer confidence, core CPI, GDP, initial jobless claims, ISM manufacturing PMI, leading index, new home sales, non-farm payroll index, Producer Price Index, retail sales excluding auto, and unemployment rate. For Fed announcements about quantitative easing, we use movements in five-year Treasury yields in tight windows around the times of the individual announcements (Table B.1 in Appendix B), taken from Chodorow-Reich (2014). As shown in Figure C.5, there is not much difference from the baseline specifications in the responses of prices, confirming the orthogonality of military spending to these factors at a daily frequency.

Considering the open economy nature of the U.S. economy. Unlike most studies that have focused a depreciation of the domestic currency in response to a positive government spending shock (e.g., Ravn et al., 2012; Ilzetzki et al., 2013; Kim, 2015; Miyamoto et al., 2019), Auerbach and Gorodnichenko (2016) found an appreciation using the same daily fiscal spending data. Given the downward pressure of domestic appreciation on import prices, the deflationary response we report might be easily explained by the appreciation of the U.S. dollar presented in Figure 2. It is also possible that domestic fiscal expansion in the U.S. economy influences commodity prices such as oil prices, feeding back into U.S. consumer prices. Despite the decreasing oil price pass-through over time (Choi et al., 2018; Yilmazkuday, 2021), this transmission channel is distinct from the exchange rate pass-through and is worth investigating.

We therefore control for 20 lags of the nominal effective exchange rate and the log of crude oil prices (West Texas Intermediate). Figure C.6 shows that controlling for the exchange rate and oil price movements hardly affects the inflation response to the government spending shock.[12] The inability of the nominal exchange movements to account for the documented response is consistent with the lower exchange rate pass-through documented for the United States (Campa and Goldberg, 2005) and for the average good priced in U.S. dollars among U.S. imports (Gopinath et al., 2010).[13] In sum, incorporating the open economy nature into the estimation framework cannot fully account for the deflationary response to the government spending shock at the ZLB.

Excluding the Great Recession period. Given the ample theoretical and empirical evidence on the asymmetric effects of government spending shocks on output between expansions and recessions (Auerbach and Gorodnichenko, 2012; Biolsi, 2017), the deflationary response found in this study might have been driven by a recession, not by the ZLB. This concern is especially valid because the Great Recession accounts for a nontrivial share of the total sample used in the baseline estimation. As shown in Figures B.1–B.6 in Appendix B, the Great Recession is characterized by extreme behavior of most of the variables considered, which is particularly visible when using daily data. To test the possibility that the deflationary response might have been driven by a recession, we re-estimate the inflation response using observations since 2010. Figure C.7 in Appendix C confirms

[12] Controlling for the growth of the nominal effective exchange rate and crude oil prices instead leads to the same result.

[13] In a recent study, Forbes et al. (2020) found that exchange rate movements caused by demand shocks such as government spending shocks consistently correspond to significantly lower pass-through than those caused by monetary policy shocks.

that the Great Recession is not a driver of the deflationary response to the government spending shock at the ZLB.

Controlling for consumer sentiment and uncertainty. The deflationary effect of government spending shocks during the ZLB period we documented might have been driven by consumer pessimism or heightened uncertainty characterizing the ZLB period. Moreover, the recent theoretical literature emphasizes the role of consumer confidence and uncertainty in the transmission of government spending shocks (e.g., Bloom, 2009; Bachmann and Sims, 2012; Mertens and Ravn, 2014).[14] In a case in which agents remained pessimistic about the future course of the U.S. economy and postponed their spending decisions, it is possible that government spending during the ZLB period would fail to boost economic activity or to create inflation.

There is also a long-standing idea that uncertainty about the economy reduces the effectiveness of economic policies (e.g., Brainard, 1967; Bloom, 2009; Baker et al., 2016). According to the uncertainty channel of fiscal policy, heightened uncertainty about the state of the economy or future economic policies might prevent an inflationary effect of government spending shocks at the ZLB, as households and firms take a "wait-and-see" approach under higher uncertainty, weakening the stimulating effect of government spending shocks. Using novel daily measures of consumer confidence and economic policy uncertainty, we test whether the presence of these channels drives our findings. Controlling for these variables hardly affects the baseline finding (see Figures C.8 and C.9 in Appendix C).[15]

[14] For example, using a structural VAR model, Bachmann and Sims (2012) show that consumer confidence is an important channel of U.S. government spending shocks. See Bloom (2009) for a discussion of how heightened uncertainty reduces the effectiveness of government policies by increasing the region of inaction of private agents.

[15] We do not find much evidence that government spending shocks induced a decline in consumer confidence or rising uncertainty at the ZLB compared to normal times. If anything, we find the opposite, especially for consumer confidence, suggesting that the confidence or uncertainty channel of fiscal policy is unlikely to explain our findings. Taking out observations from during the Great Recession, which are associated with a sharp decline in consumer confidence and heightened uncertainty, does not change this narrative. These results are available upon request.

C. Additional exercises: ZLB vs. non-ZLB

While the theoretical prediction of the standard New Keynesian model provides a clear answer regarding the inflation response to government spending shocks at the ZLB, the response during normal times is *a priori* unclear. In practice, it depends on many factors, especially how responsive the monetary policy is under the Taylor rule. Thus, to investigate whether the inflation response differs between normal times and the ZLB period, we use additional observations before the Federal Reserve lowered its policy rate in December 2008 and after the Federal Reserve lifted that rate in December 2015. The following analysis is somewhat constrained by data availability, as we can extend only the payment series. Both the beginning (July 2008) and the ending period (April 2018) are chosen based on the availability of the daily OPI series.

Figure 5. Response to government spending shocks: post-ZLB period (January 2016 – April 2018)

Note: This figure shows the impulse responses of the six variables of interest (exchange rate, price level, expected inflation, ex-post and ex-ante real interest rate, and business conditions) to a unit shock to treasury payments using a subsample that covers the post-ZLB period. The dashed lines denote 68% and 90% confidence intervals. The estimation sample is from January 4, 2016, to April 13, 2018.

As a first exercise, we analyze the effects of the shock to payments to defense contractors using the observations from the post-ZLB period only (January 2016 to April 2018). Figure 5 presents responses to the payment shock of the nominal effective exchange rate, price level, five-year-ahead break-even inflation, actual real interest rate, expected real interest rate (five-year-ahead), and economic conditions measured by the ADS index. One should note that the results, in general, are not statistically significant, probably because of the shorter sample period, and are therefore only suggestive.

While we find somewhat different responses for every variable, the price response is most striking. Unlike the ZLB case, the response becomes inflationary and highly statistically significant for the first two months. The response of inflation expectations is less clear-cut, but it does not decrease. What matters for our findings is not the increase in prices *per se*, but the opposite response compared to the ZLB episode, as this response makes it even more difficult to reconcile our findings with the prediction of standard New Keynesian models. We do not find much evidence for a rising real interest rate, which should be the case if the monetary authority actively responds to inflation. Perhaps the monetary authority did not respond to such a temporary increase in prices, which appears reasonable given the persistence of the short-term policy rate. Interestingly, we find an insignificant but expansionary effect of government shocks in the positive response of daily business conditions.

As noted, despite the use of daily data, this subsample analysis might suffer from insufficient statistical power. Thus, as a second exercise, we exploit the state-dependent local projection method, enhancing estimation efficiency by using an effectively larger sample. Differences in the effects of the government spending shock between normal times and the ZLB period, shown in Figure 6, largely confirm the results in Figure 5.[16] Outside the ZLB period, we find a stronger inflationary response and a significant decline in the ex-post real interest rate, especially in the short run. This finding is precisely opposite to those of the theoretical models, which predict a larger multiplier at

[16] To enhance the readability of graphs, we plot only the 68% confidence intervals for the state-dependent models.

the ZLB via a decline in the real interest rate (e.g., Christiano et al., 2011; Eggertsson, 2011; Woodford, 2011).

Figure 6. State-dependent response to government spending shocks: ZLB vs. normal times

Note: This figure shows the state-dependent impulse response of the four variables of interest (exchange rate, price level, ex-post real interest rate, and business conditions) to a unit shock in treasury payments. The red line illustrates the impulse response at the ZLB; the blue line denotes the response during normal times. The dashed lines and the shaded area denote 68% confidence intervals. The estimation sample is from July 1, 2008, to April 13, 2018.

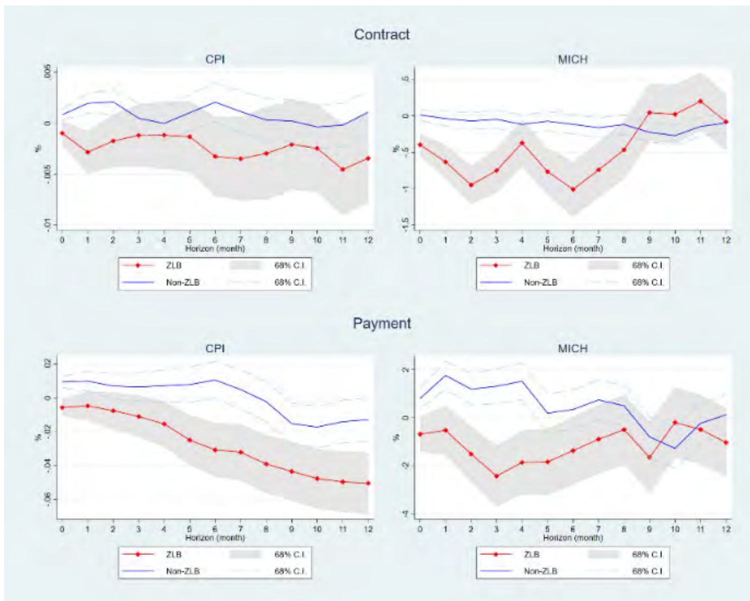
Considering the intensity of the ZLB constraints. While we have used a binary indicator to differentiate the ZLB period from normal times, economic agents did not necessarily have the same expected duration of the binding ZLB over time. For example, it is possible that agents in 2009, shortly after the aggressive rate cut by the Fed, might have initially thought that monetary policy would normalize soon. After multi-rounds of large-scale asset purchases (LSAPs) or forward guidance, agents could have switched their belief that the Fed would keep the policy rate at the lower bound for an extended period. Indeed, the expected duration of the binding ZLB is crucial in determining the size of the government spending multiplier in many theoretical models of the ZLB. However, using a binary indicator as in the baseline analysis treats all ZLB periods the same, ignoring the degree to which the ZLB constraint actually binds when households and firms make consumption and investment decisions.

To guard against this possibility, we use a measure of the market-implied probability of being at the ZLB based on the overnight index swap (OIS) market, taken from Moessner and Rungcharoenkitkul (2019). The OIS-implied ZLB probability is obtained via rate decision tree calculations from Bloomberg using OIS forward rates 50 basis points below the FOMC meeting date around nine months ahead. The accounting of this de-facto ZLB episode extends the methodology in Swanson and Williams (2014), which computed the sensitivity of government yields at different maturities to macroeconomic news to measure the degree to which monetary policy is constrained. They found that one- and two-year Treasury yields were surprisingly unconstrained throughout 2009 and 2010, although the effective Federal Funds rate had already reached the ZLB. Figure B.7 in Appendix B plots the implied probability of the binding ZLB constraint (P_t) during the sample period.

We replace the binary indicator I_t in Equation (2) with the implied probability P_t, which allows us to utilize the intensity of the ZLB and re-estimate Equation (2). The patterns of state-dependent responses to government shocks in Figure C.10 in Appendix C are similar to the results in Figure 6, suggesting that accounting for the intensity of the ZLB constraint does not overturn our main findings. In particular, we still find a stronger inflationary response during normal times, resulting in a decline in the real interest rate.

Monthly frequency analysis using a longer sample. Despite our effort to demonstrate the difference between the ZLB and normal times, using only ten years of data, as shown in Figure 6, might induce skepticism about our findings. To address this issue, we employ a standard monthly CPI as a dependent variable and use defense spending aggregated up the monthly level as a shock variable; we then estimate the monthly version of Equation (2). We further control for the current and 12 lags of the unemployment rate and the federal funds rate to reflect changes in economic conditions and monetary policy. While these specifications impose a stronger timing assumption than the baseline analysis in identifying a structural government spending shock, the assumption is still plausible compared to those in many studies using quarterly variables, such as Blanchard and Perotti (2002)

Figure 7. State-dependent response to government spending shocks: ZLB vs. normal times using monthly data



Note: This figure shows the state-dependent impulse response of prices and consumer inflation expectations to a unit shock in defense spending (contract announcements and actual payments) at a monthly frequency. The red diamond line illustrates the impulse response at the ZLB; the blue line denotes the response during normal times. The dashed lines and the shaded area denote 68% confidence intervals. The estimation sample is from 1996M1 to 2018M3.

In the left panel of Figure 7, using a longer period of monthly data, we confirm our main finding that government spending shocks are more deflationary at the ZLB. In fact, government spending shocks tend to be inflationary during normal times, providing a potential explanation for the mixed findings in the literature on the sign of the price response. As summarized in Table 1, these previous studies typically estimated the average response of prices to government spending shocks over the entire sample, but the sample periods under study were not the same. When they engaged in subsample analysis, some of these studies found contrasting responses of prices and inflation across subsamples, similar to our results here.[17] We add to the fiscal price puzzle by showing that ignoring the distinct feature of the ZLB episode can be one reason for findings in the literature of mixed price responses to a government spending shock.

We also investigate the response of one-year inflation expectations using the Michigan Consumer Survey (the right panel in Figure 7), which is free of the bias induced by risk premia in break-even inflation considered in Section III.A. The response of inflation expectations provides even more clear-cut evidence that government spending shocks are deflationary at the ZLB but inflationary during normal times (especially for a payment shock), thereby further validating our conclusion using high-frequency data.[18] The state-dependent pattern in the response of inflation expectations is robust when using the one-year inflation expectation rate from the Federal Reserve Bank of Cleveland.

IV. DISCUSSION OF FINDINGS

Credit constraints and the effects of government spending shocks. How do we reconcile the robust evidence of a deflationary response to a government spending shock at the ZLB? This finding is in sharp contrast to the theoretical prediction of the standard New Keynesian model. Among various twists of this class of models introduced below, we view the explanation based on credit constraints as most appealing. This is because the binding ZLB period largely overlapped with a period of tightening financial conditions and binding credit constraints. Recently, Abo-Zaid and Kamara

[17] To the extent that the ZLB characterizes an extreme form of passive monetary policy, our finding is consistent with Mumtaz and Theodoridis (2020) and Jørgensen and Ravn (2022), who use a longer quarterly sample in their VAR exercises. Using subsample analysis, they show that the response of inflation to government spending shocks was less inflationary (or more deflationary) when monetary policy was passive (before the Volcker regime). In addition, Jørgensen and Ravn (2022) find that the price response becomes more deflationary once the ZLB period is added to the sample.

[18] Figure C.11 in Appendix C confirms that the estimated IRFs hardly change when excluding the post-ZLB period for defense payments (after December 2015), suggesting that our earlier finding using the post-ZLB daily data is not driven by a potential structural change in the relationship between government spending and prices after the ZLB.

(2020) show theoretically that credit constraints weaken the inflation channel of government spending shocks; as a result, positive government spending shocks can be deflationary at the ZLB.

Abo-Zaid and Kamara (2020) extend the standard New Keynesian model by introducing constrained (impatient) households whose borrowing is tied to the value of their houses. In their TANK model, credit constraints reduce the ability of constrained households to borrow and, consequently, limit the increase in their consumption in response to a government spending shock. In turn, the increase in inflation and expected inflation following the shock is limited. With active monetary policy, such a weaker inflation response than that predicted by the model without credit constraints curbs the rise in the real interest rate, thereby mitigating the crowding-out effect on consumption. However, when the economy is subject to the ZLB, a weaker response in inflation translates into a higher real interest rate and discourages consumption compared to normal times, which feeds back into a weaker inflation response. As a result, the inflation response is not as strong as it would be in a model with no constraints, and government spending shocks can be deflationary with sufficiently tight credit constraints (see Figure 2 in their paper).

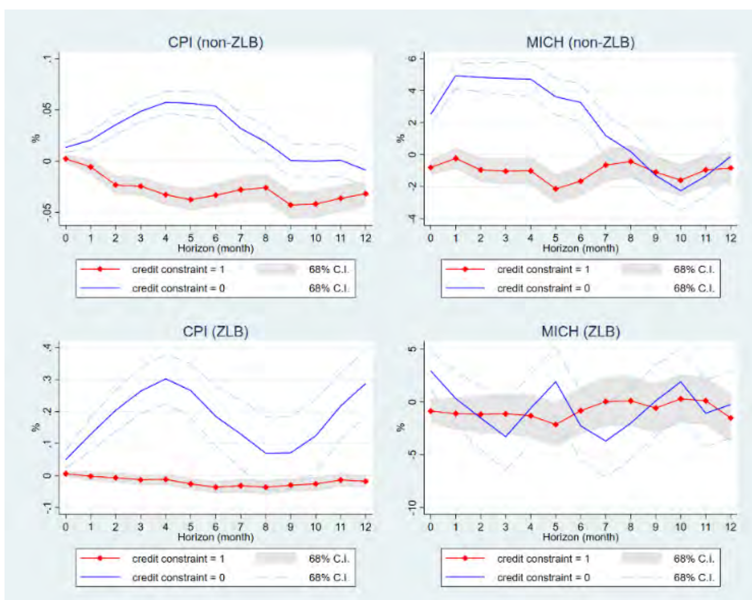
We test the empirical relevance of the credit constraint channel by using real housing prices as a proxy for the tightness of household credit constraints. We HP-filter real housing prices and define a period with tighter credit constraints when the residual takes a negative value (i.e., below the trend). To avoid an end-point problem in HP-filtering, we use a sample from 1994M1 to 2018M12, whereas the estimation sample is from 1996M1 to 2018M3.[19] As shown in Figure B.8 in Appendix B, the ZLB period overlaps with tighter household credit constraints, which could weaken the inflation channel of government spending. From 1994M1 to 2018M12, the ZLB period accounts for

[19] See, for example, Alpanda and Zubairy (2019) for a similar example of HP-filtering used to disentangle the cyclical component of household debt from the long-run trend induced by financial deepening and a method to avoid an end-point problem.

28.3% of the total sample. Within the ZLB period, the tightened constraint period accounts for 54.1% (46 monthly observations).

We augment Equation (2) with an additional binary state to capture the tightness of the credit constraints defined above. In Figure 8, we confirm that defense spending shocks are indeed more deflationary (or less inflationary) when household credit constraints tighten. A similar conclusion is obtained using inflation expectations from the Michigan survey. The wider confidence interval for the ZLB state reflects that the ZLB is a small fraction of the total sample. On the other hand, when credit constraints are relaxed, government spending shocks are indeed more inflationary at the ZLB than during normal times, consistent with the standard theoretical prediction. This finding is not only consistent with the theoretical prediction of Abo-Zaid and Kamara (2020) but also reconciles the empirical anomaly documented in Figure 3 with standard New Keynesian models.

Figure 8. State-dependent response to government spending shocks: ZLB vs. normal times and the role of credit constraints



Note: This figure shows the state-dependent impulse response of prices and consumer inflation expectations to a unit shock in treasury payments at a monthly frequency. The upper panel shows the response during normal times; the lower panel shows the response at the ZLB. The red diamond line illustrates the impulse response when credit constraints are tightened; the blue line denotes the response when credit constraints are relaxed. The dashed lines and the shaded area denote 68% confidence intervals. The estimation sample is from 1996M1 to 2018M3.

Other potential explanations from existing studies. Despite the theoretical appeal, the model with credit constraints is not the only one that is compatible with our findings. In this section, we introduce relevant recent works that, in our view, offer promising extensions to the basic New Keynesian framework and that might help make the model more consistent with our empirical findings and provide understanding at the root of the fiscal price puzzle. A promising avenue is to introduce deep habit formation (Zubairy, 2014), learning-by-doing (d'Alessandro et al., 2019), or variable technology utilization (Jørgensen and Ravn, 2022) into an otherwise standard medium-scale New Keynesian model, assume monetary policy inertia at the ZLB (Hills and Nakata, 2018), and consider realistic substitutability between private and government consumption (Ercolani and e Azevedo, 2019).

Zubairy (2014) highlights the role of countercyclical markups—endogenously generated by deep habits—in propagating fiscal shocks. Since markups are countercyclical, a government spending shock can lead to a decline in inflation. d'Alessandro et al. (2019) empirically show that a government spending shock is deflationary and reconcile their finding by introducing skill accumulation through past work experience. As a result, TFP increases in response to a government spending increase, which reduces future marginal costs and expected inflation. However, these studies do not account for how the presence of the ZLB affects their conclusion.

In the study most related to ours, Jørgensen and Ravn (2022) show that variable technology utilization allows firms to accommodate increased demand following fiscal expansion by adopting new technology into the production process. The resulting increase in measured productivity leads to a decline in prices, translating into an increase in the real interest rate in the face of the ZLB, dampening private economic activity. Similar to the credit constraint channel of Abo-Zaid and Kamara (2020), their model can generate a smaller government spending multiplier at the ZLB than during normal times.

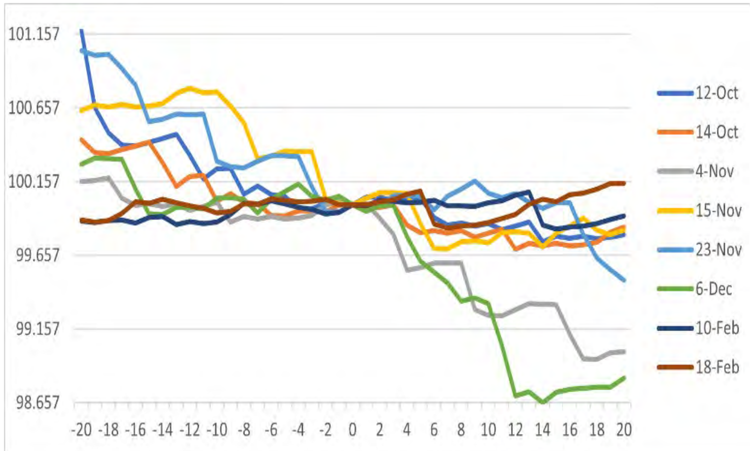
Hills and Nakata (2018) show that an economy with policy inertia can bring the prediction of the New Keynesian model closer to our empirical findings. Policy inertia reduces the government spending multiplier by reducing the effects of government spending shocks on expected inflation. Ercolani and e Azevedo (2019) showed that using recent estimates of the degree of substitutability between private and government consumption in an otherwise standard New Keynesian model can make government spending less inflationary, thereby reducing the size of government spending multipliers obtained when the nominal interest rate is zero.[20] However, the use of defense spending in our analysis suggests that the substitutability between private and government consumption cannot fully explain the deflation anomaly.

Revisiting daily price movements around the 2009 American Recovery and Reinvestment Act. Despite the statistical significance of the estimated effect of daily defense spending shocks on prices, the very nature of this effect still casts doubt on the economic significance of our findings. This concern warrants further investigation because there was no major military event like a war in our main sample. We instead use major fiscal news events during our sample: the 2009 American Recovery and Reinvestment Act.

Our approach is twofold. First, we conduct an event study in the spirit of Dupor and Li (2015), documenting short-run price changes around these fiscal events. Figure 9 shows that news about this massive future government spending is mostly followed by a decline in prices between 2008 and 2009, during which households faced tighter credit constraints. The finding that there is no visible increase in prices after these fiscal news events is consistent with Dupor and Li (2015), who found no increase in inflation expectations, measured by break-even inflation using TIPS, following the same events.

[20] When private and (non-military) government consumption are substitutable, an increase in government consumption reduces the marginal utility of private consumption, leading agents to partially substitute private consumption with newly available government consumption. As a result, aggregate demand is lower than in the case of "separable" utility, reducing input prices and marginal costs, and therefore inflation.

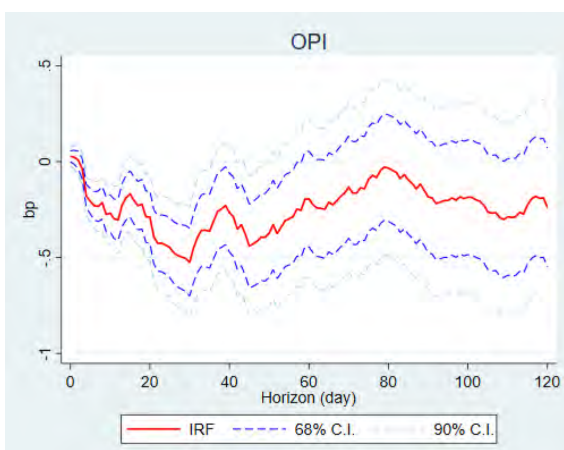
Figure 9. Movements in the OPI around each fiscal news date



Note: This figure shows the movements in the online price index in the 41-day window (20 days before the date of release and 20 days after) around fiscal news release dates. The level of the index is normalized to 100 on the news release date.

Second, we use these eight fiscal news events as a dummy variable in our local projections. We use the same specification as in the baseline analysis and replace the daily defense spending series with fiscal news dummies. As shown in Figure 10, we still find a deflationary effect of a fiscal news shock in the short run. Together with Figure 9, this finding reassures that our main finding is not simply driven by using a particular component (defense spending) of government expenditures.

Figure 10. Price response to fiscal news shocks



Note: This figure shows the impulse response of the price level using the daily online price index to a fiscal news shock. The shock is a dummy variable with the value of one on the date of news release regarding the American Recovery and Reinvestment Act. The dashed lines denote 68% and 90% confidence intervals. The estimation sample is from December 1, 2008, to March 28, 2014.

V. Conclusion

Our work fits broadly into a growing literature testing predictions of the textbook New Keynesian model when the ZLB is binding. Amid the rapid expansion in the theoretical literature on the ZLB, empirical studies often yield puzzling departures from standard theoretical predictions. For example, Dupor and Li (2015) find that the inflation response during the recent ZLB period does not align with predictions of the textbook New Keynesian model. Garín et al. (2019), using a local projection, confirm that the effects of supply shocks on output and inflation at the ZLB are inconsistent with the predictions of the standard New Keynesian model. Wieland (2019), using a case study on the Great East Japan Earthquake and oil supply shocks, shows that the binding ZLB does not necessarily increase fiscal multipliers. In these studies, the inflation channel plays an important role in determining the size of the fiscal multiplier at the ZLB, showing the need for more empirical studies in this area.

Our study's sharpened identification, obtained using high-frequency data, contributes to understanding the discrepancy between model and data. In particular, our novel finding of a deflationary response to government spending at the ZLB is not easily squared with standard theoretical models. We thus have provided an overview of the recent development in the theoretical literature to help understand this anomaly. While we present a consistent explanation for the deflationary effect of government spending at the ZLB via the credit constraint channel, further research to confirm our findings using non-defense government spending and alternative empirical specifications will be fruitful.

Our novel findings also contribute to the recent debate on the effectiveness of fiscal stimulus and ultra-accommodative monetary policy in response to the COVID-19 pandemic (e.g., Chetty et al., 2020; Guerrieri et al., 2020). Although the U.S. economy has since March 2020 again fallen into the realm of ZLB, this does not necessarily guarantee a larger fiscal multiplier resulting from fiscal expansion if an increase in government spending fails to increase inflation. Thus, more careful analysis, possibly using a real-time tracker, should be conducted before making any pre-emptive justifications for the unprecedented level of fiscal stimulus.

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Online Appendix

"Are Government Spending Shocks Inflationary at the Zero Lower Bound? New Evidence from Daily Data"

A. Simple model

Using a simplified theoretical framework, we illustrate how the binding ZLB strengthens the inflationary response to government spending shocks, further stimulating consumption and output compared to normal times. Although the model is highly stylized, it provides analytical solutions, enabling straightforward comparative statistics. Moreover, this study shares its theoretical predictions with more sophisticated medium-scale New Keynesian models (e.g., Smets and Wouters, 2003).

Considering the standard dynamic New Keynesian model characterized by Calvo pricing, linear labor-only production technology, and separable consumption and leisure in the utility function (e.g., Carlstrom et al., 2014; Dupor and Li, 2015), the linearized model is given by

$$i_t - E_t\pi_{t+1} = -\sigma(c_t - E_t c_{t+1}), \tag{A.1}$$

$$\pi_t = \beta E_t \pi_{t+1} + \kappa m c_t, \tag{A.2}$$

$$mc_t = \sigma c_t + \nu y_t, \tag{A.3}$$

$$y_t = (1-s)c_t + s g_t, \tag{A.4}$$

where $\pi_t, y_t, c_t, g_t, mc_t$, and i_t denote inflation, output, consumption, government spending, marginal cost, and the nominal interest rate, respectively, all measured as deviations from the steady state. Additionally, for simplicity, we assume that steady-state inflation is zero. The constant s is the share of government spending in the steady state.[21] Substituting Equations (A.3) and (A.4) into Equation (2), we have

$$\pi_t = \beta E_t \pi_{t+1} + \kappa(\sigma + \nu(1-s))c_t + \kappa\nu s g_t. \tag{A.5}$$

The simple dynamic New Keynesian model is given by the dynamic IS curve (A.1), New Keynesian Phillips curve (A.5), the monetary policy rule (A.6), and the fiscal policy rule (A.7). Following Dupor and Li (2015), the monetary and fiscal policies are set according to the following:

$$i_t = \psi E_t \pi_{t+1}, \tag{A.6}$$

$$g_t = \rho g_{t-1} + \varepsilon_t, \tag{A.7}$$

where ε_t is the mean zero white noise. The monetary policy is considered active when the responsiveness parameter $\psi > 1$, and passive otherwise.

Given Equations (A.1), (A.5), and (A.6) and the endogenous variables c_t, i_t, and π_t, one can solve for the model's rational expectations equilibria around its steady state. The equilibrium is typically unique under an active monetary policy, whereas multiple equilibria exist under a passive monetary policy. Following Boivin and Giannoni (2006) and Dupor and Li (2015), we only focus on the bubble-free equilibrium to rule out multiple equilibria. Regardless of monetary policy, inflation and consumption in equilibrium are given by

$$\pi_t = \Lambda g_t = \frac{\kappa s \nu(1-\rho)}{\beta(\rho^2 + \Theta\rho + \frac{1}{\beta})} g_t, \tag{A.8}$$

$$c_t = \Omega g_t = \frac{(1-\beta\rho)\Lambda - \kappa s \nu}{\kappa(\sigma + \nu(1-s))} g_t, \tag{A.9}$$

[21] As in Dupor and Li (2015), Equations (A.1) to (A.5) do not include a government budget constraint because we assume that fiscal policy is Ricardian. Thus, the government's present value budget condition holds for any sequence of prices and quantities as long as the fiscal rule is followed. This assumption allows us to focus on the inflation channel of government spending shocks amplified by the ZLB.

where $\Theta = \frac{\sigma^{-1}\kappa(\sigma+\nu(1-s))(\psi-1)-\beta-1}{\beta}$. It can be clearly seen that when $\psi = 1$, $\Lambda = \frac{\kappa s \nu}{1-\beta\rho} > 0$.[22] When the monetary authority raises the nominal interest rate one for one with expected inflation, a government spending shock increases inflation. Given this value of Λ, we can easily confirm that $\Omega = 0$. Government spending shocks do not crowd out nor crowd in private consumption when ψ equals one. For a reasonable value of ψ, we have $\frac{\partial \pi_t}{\partial g_t} > 0$. Moreover, when $\psi < 1$, $\frac{\partial c_t}{\partial g_t} > 0$, and when $\psi > 1$, $\frac{\partial c_t}{\partial g_t} < 0$.

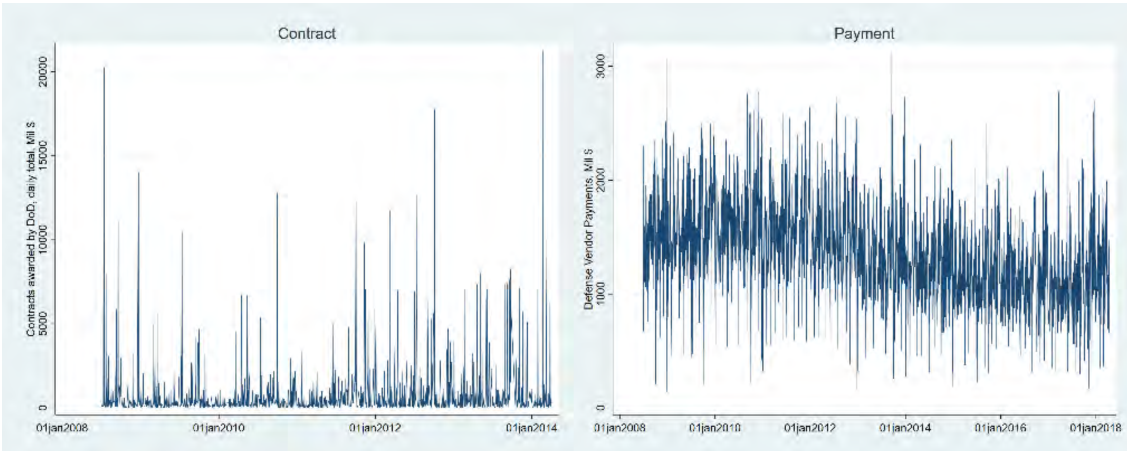
Our research interest is observing how the binding ZLB amplifies the inflation response and, therefore, the consumption (and output) response to government spending shocks. At binding ZLB, $\psi \to 0$ so that the monetary authority keeps the nominal interest rate at zero regardless of inflation. Although this simple model does not consider the binding ZLB in the strict sense, the following mechanism generating a higher multiplier via an increase in (expected) inflation is shared by theoretical models considering the ZLB explicitly (e.g., Christiano et al., 2011; Eggertsson, 2011; Woodford, 2011).

As ψ only affects Λ via changes in Θ, it is clear that $\frac{\partial}{\partial \psi}\left(\frac{\partial \pi_t}{\partial g_t}\right) < 0$, and therefore, $\frac{\partial}{\partial \psi}\left(\frac{\partial c_t}{\partial g_t}\right) < 0$. The inflationary response to government spending shocks is maximized at the ZLB, which also maximizes the size of the fiscal multiplier. Figure 1 in the main text, taken from Dupor and Li (2015), plots the equilibrium impact responses of inflation and consumption to a government spending shock under the active and passive monetary policy, depending on the value of ψ.

[22] Because σ, κ, $\nu \geq 0$ and $1 > \beta$, $\rho \geq 0$, Λ must be positive.

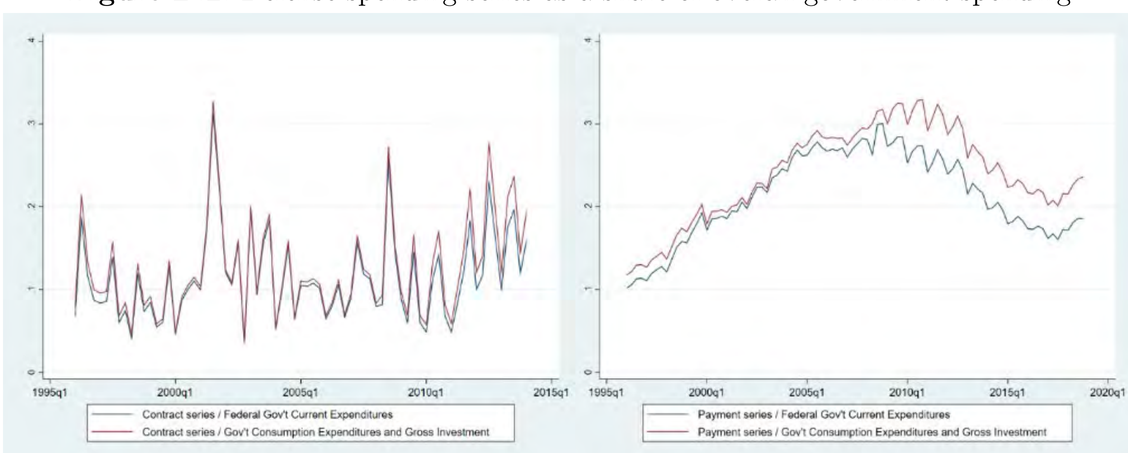
B. Data

Figure B.1. Daily measures of defense spending



Note: This figure plots two daily series of government spending constructed by Auerbach and Gorodnichenko (2016). The left panel shows the first spending series—announced volume of contracts awarded daily by DoD—that covers the sample period from July 1, 2008, to March 28, 2014; the right panel presents the extended second spending series—payments to defense contracts—that covers the sample period from July 1, 2008, to April 13, 2018.

Figure B.2. Defense spending series as a share of overall government spending

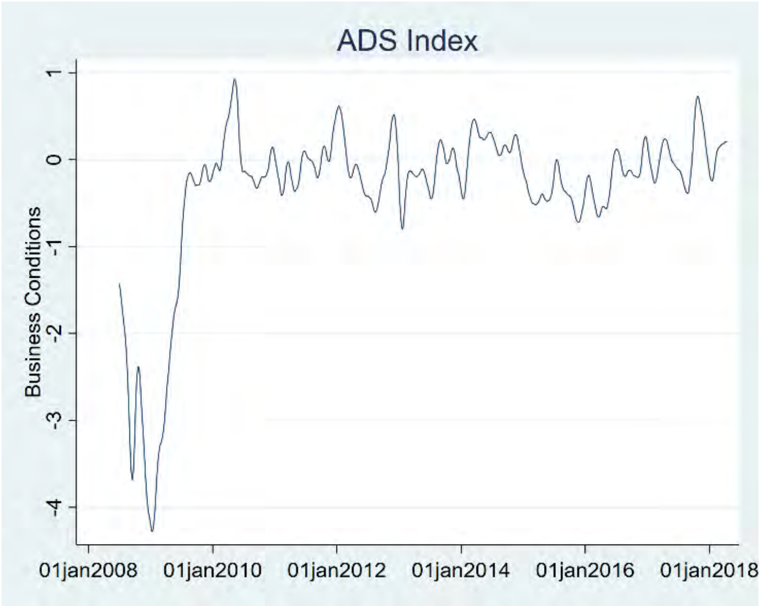


Note: This figure plots the ratio of the two defense spending series (contract announcements and actual payments) to total government expenditure at a quarterly frequency. The daily data are summed up to produce quarterly values. Both the federal government's current expenditures and government consumption and gross investment are used for normalization.

Figure B.3. Daily online price index (OPI) and consumer price index (CPI)

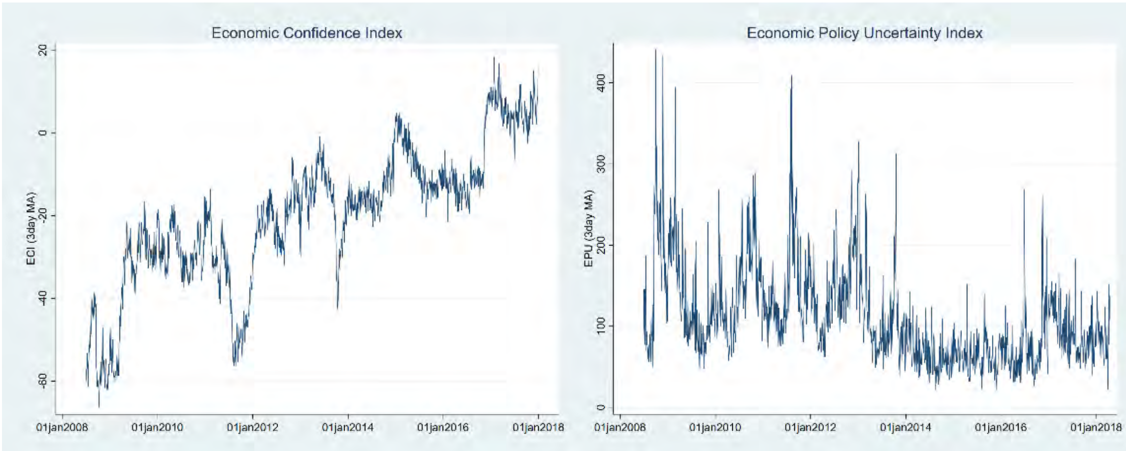
Note: This figure plots the daily time series of the U.S. online price index and the consumer price index released by the Bureau of Labor Statistics for the sample period between July 1, 2008, and April 13, 2018. The indices are normalized by the first observation of each series.

Figure B.4. Daily business conditions (ADS Index)



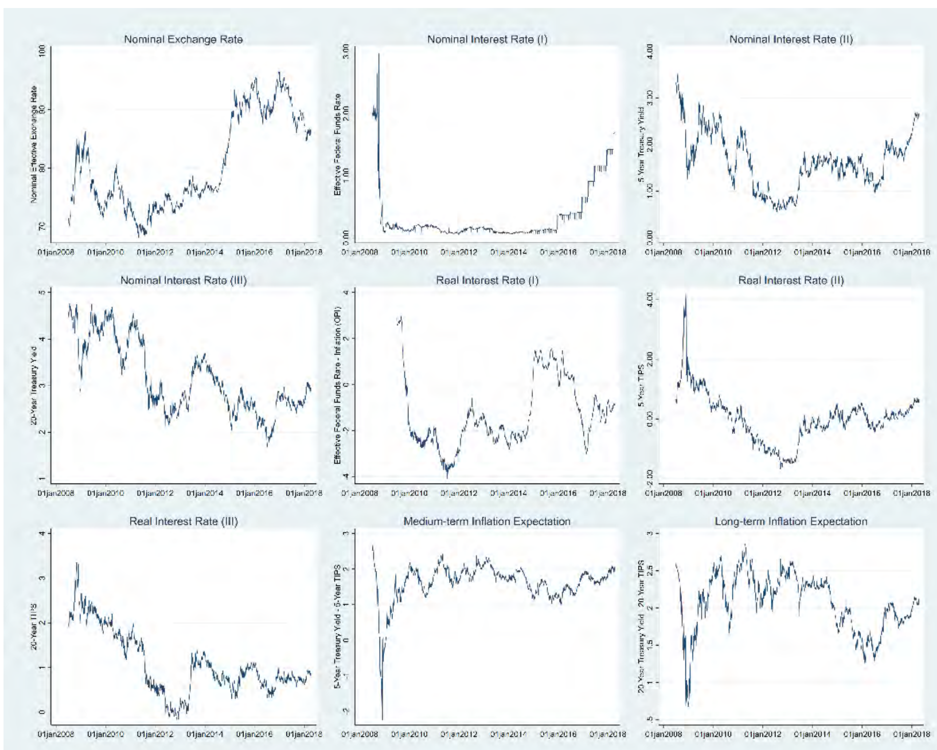
Note: This figure plots the daily time series of the Aruoba-Diebold-Scotti business conditions index (ADS Index) from Aruoba et al. (2009) for the sample period between July 1, 2008, and April 13, 2018.

Figure B.5. Daily consumer confidence (Gallup ICS) and economic policy uncertainty



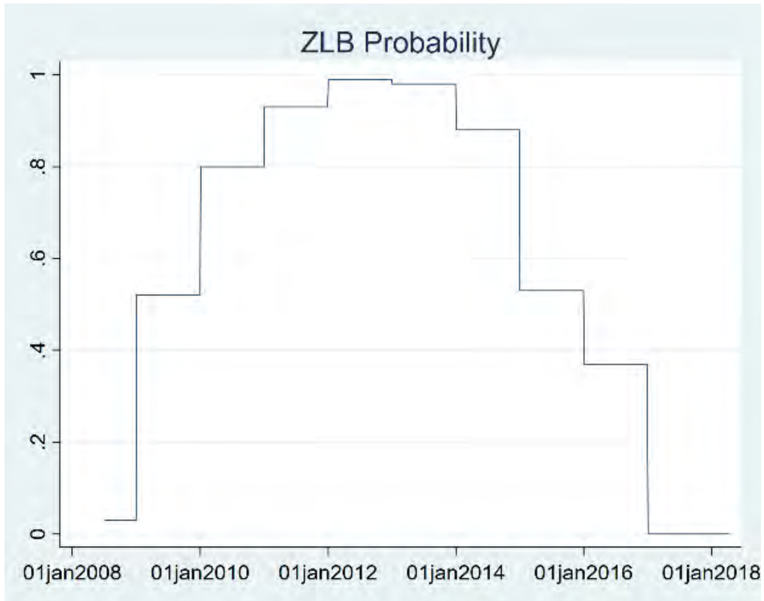
Note: This figure plots the daily time series of the Economic Confidence Index (ECI) and Economic Policy Uncertainty Index (EPU Index) for the sample period between July 1, 2008, and April 13, 2018.

Figure B.6. Evolution of the main variables used in the analysis



Note: This figure plots the daily time series of nine variables of our interest (nominal effective exchange rate, effective Federal Funds rate, 5-year Treasury yield, 20-year Treasury yield, ex-post and two ex-ante real interest rates, and two inflation expectation measures). The sample period is between July 1, 2008, and April 13, 2018.

Figure B.7. Implied probability of the ZLB



Note: This figure presents a time-series graph for the OIS-Implied ZLB probability, which is the probability of the U.S. OIS rates below 50 bp around nine months ahead.

Figure B.8. Household credit constraints proxied by real housing prices

Note: This figure presents the HP-detrended real housing prices as a proxy for household credit constraints. The positive (negative) value denotes a period with relaxed (tightened) constraints. To avoid an end-point problem in HP-filtering, we use the sample from 1994M1 to 2018M12.

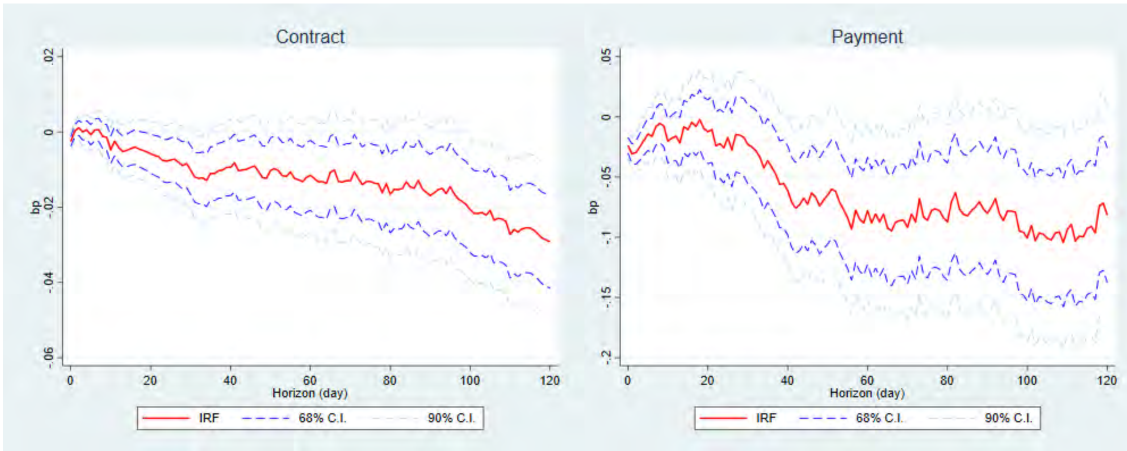
Table B.1. List of FOMC events at the ZLB

Episode	Date	Time	Event	Effect on 5-year notes (bp)
QE1	December 1, 2008	13:45	Bernanke Speech	-9.2
QE1	December 16, 2008	14:21	FOMC Statement	-16.8
QE1	January 28, 2009	14:15	FOMC Statement	3.1
QE1	March 18, 2009	14:17	FOMC Statement	-22.8
QE1	September 23, 2009	14:16	FOMC Statement	-8.9
QE2	August 10, 2010	14:14	FOMC Statement	-5.8
QE2	September 21, 2010	14:14	FOMC Statement	-1.8
FG	August 9, 2011	14:18	FOMC Statement	-14.4
FG	January 25, 2012	12:28	FOMC Statement	-6.3
QE3	September 13, 2012	12:31	FOMC Statement	6.4
QE3	May 22, 2013	10:30	Bernanke Testimony	6.6
QE3	June 19, 2013	14:00	FOMC Statement	7.8
QE3	July 10, 2013	16:45	Bernanke speech	-7.3
QE3	September 18, 2013	14:00	FOMC Statement	-14

Note: This table summarizes the effect of the unconventional monetary policy as defined in Chodorow-Reich (2014). The effect is measured as the change in the yield-to-maturity of the five-year Treasury note from the five-minute window ending two minutes before the announcement to another five-minute window beginning 18 minutes after the announcement.

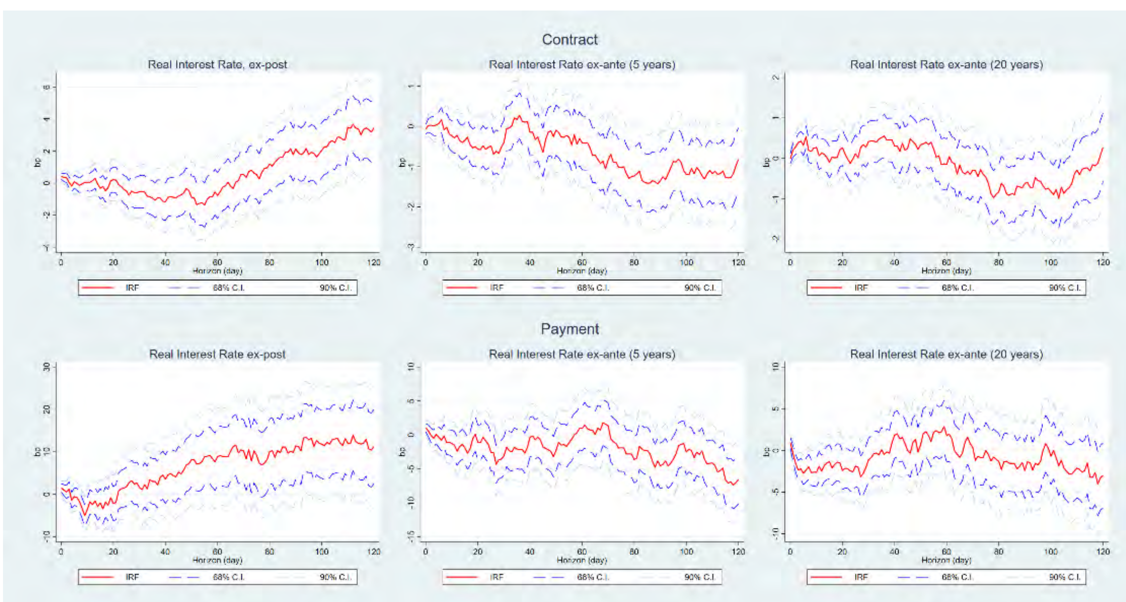
C. Robustness checks

Figure C.1. Inflation response to government spending shocks: without the ADS index



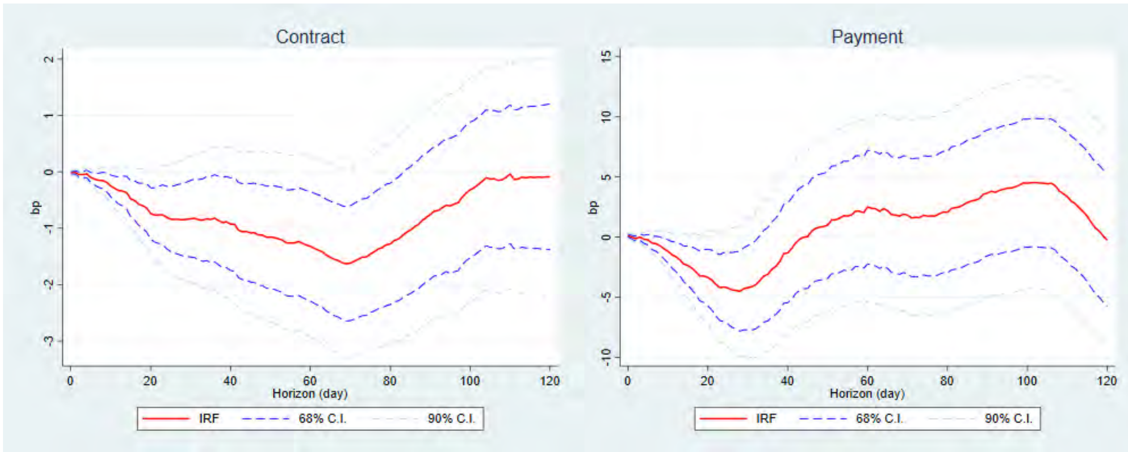
Note: This figure shows the impulse response of the price level using the daily online price index without controlling for 20 lags of the ADS index. The left panel shows the response to a unit shock to DoD contract; the right panel shows the response to a unit shock to treasury payments. The dashed lines denote 68% and 90% confidence intervals. The estimation sample is from December 1, 2008, to March 28, 2014.

Figure C.2. Real interest rate response to government spending shocks



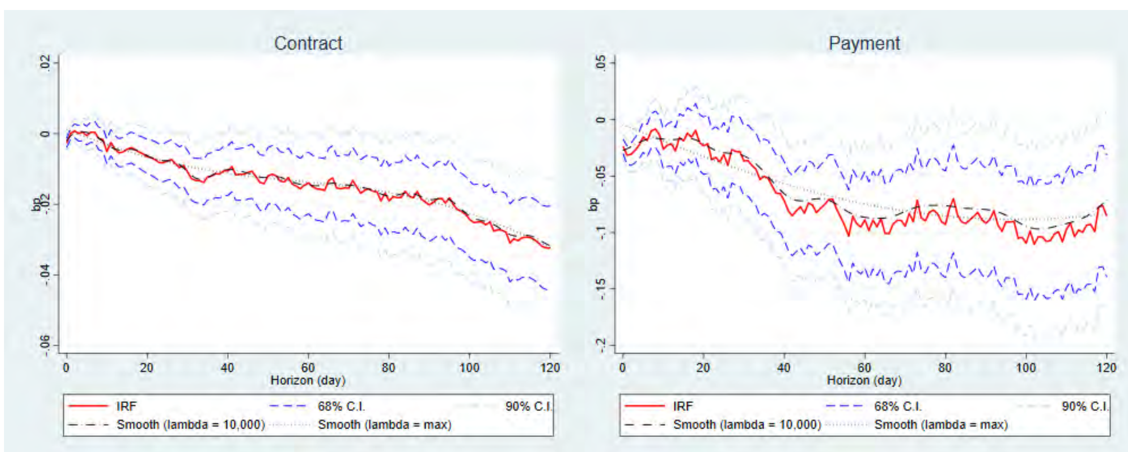
Note: This figure shows the impulse response of different types of real interest rates: ex-post real interest rate using the difference between effective Federal Funds rate and realized OPI inflation (left), TIPS with 5- and 20-year maturities (center, right). The upper panels show the response to a unit shock to the DoD contract; the lower panel shows the response to a unit shock to treasury payments. The dashed lines denote 68% and 90% confidence intervals. The estimation sample is from December 1, 2008, to March 28, 2014.

Figure C.3. Economic activity response to government spending shocks



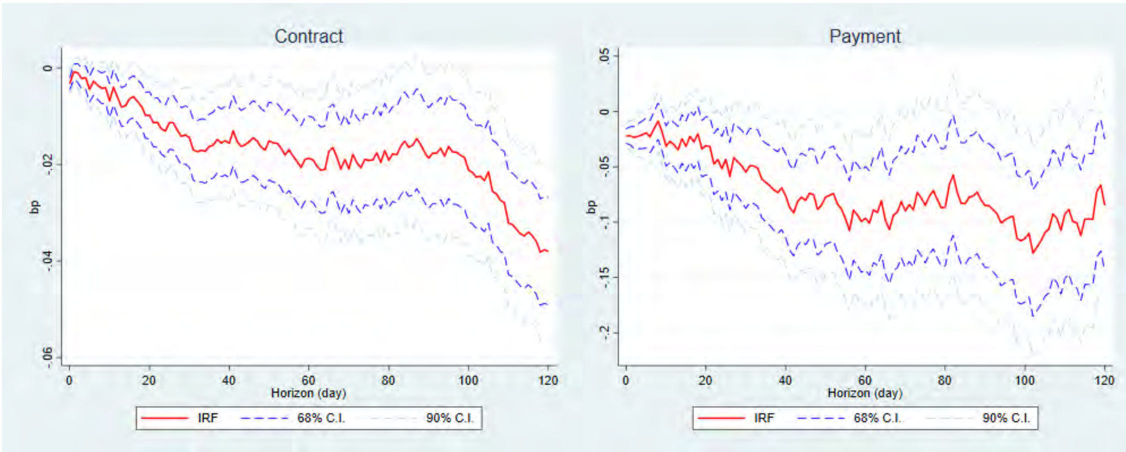
Note: This figure shows the impulse response of the economic conditions using the daily ADS index. The left panel shows the response to a unit shock to DoD contracts; the right panel shows the response to a unit shock to treasury payments. The dashed lines denote 68% and 90% confidence intervals. The estimation sample is from December 1, 2008, to March 28, 2014.

Figure C.4. Price response to government spending shocks using SLP



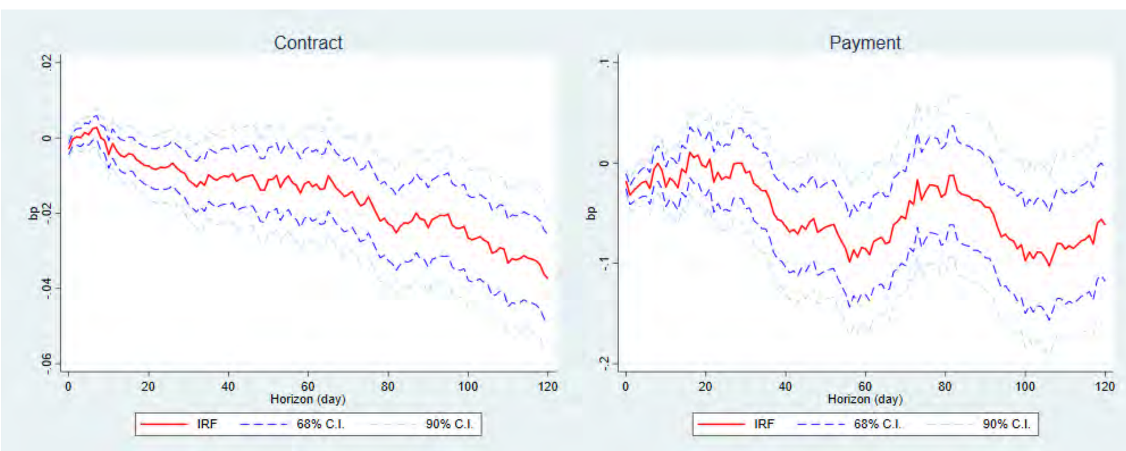
Note: This figure shows the impulse response of the price level using the daily online price index. The left panel shows the response to a unit shock to DoD contracts; the right panel shows the response to a unit shock to treasury payments. The panels show the impulse response of local projections (red) and smooth local projections (black) using different degrees of shrinkage, with dashed lines denoting estimates obtained using a lower degree of penalization. The estimation sample is from December 1, 2008, to March 28, 2014.

Figure C.5. Price response to government spending shocks: controlling for macroeconomic news and the Fed's announcements



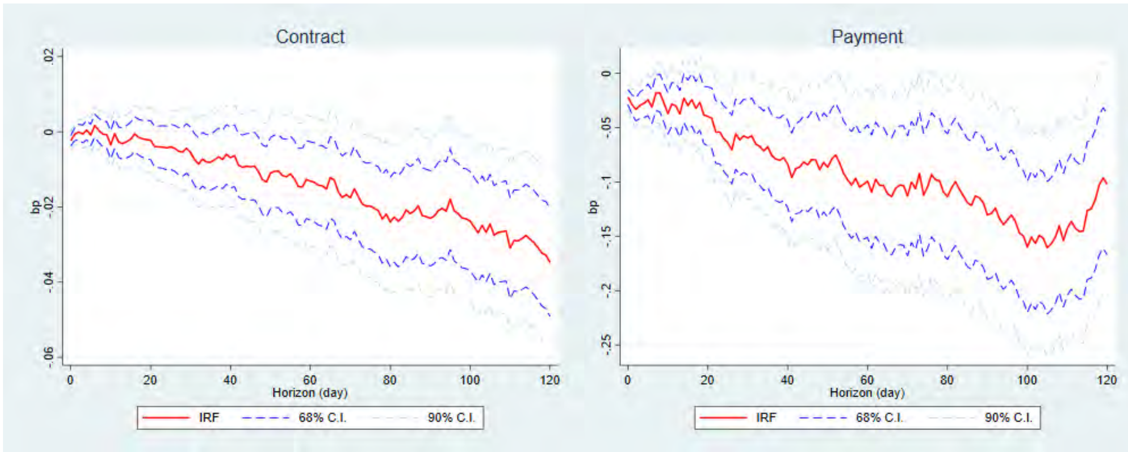
Note: This figure shows the impulse response of the price level using the daily online price index. The left panel shows the response to a unit shock to DoD contracts, and the right panel shows the response to a unit shock to treasury payment. Contemporaneous and lagged values to 20 days of surprise components of the macroeconomic news release and monetary policy are controlled in addition to the baseline specification. The dashed lines denote 68% and 90% confidence intervals. The estimation sample is from December 1, 2008, to March 28, 2014.

Figure C.6. Price response to government spending shocks: controlling for the nominal exchange rate and oil prices



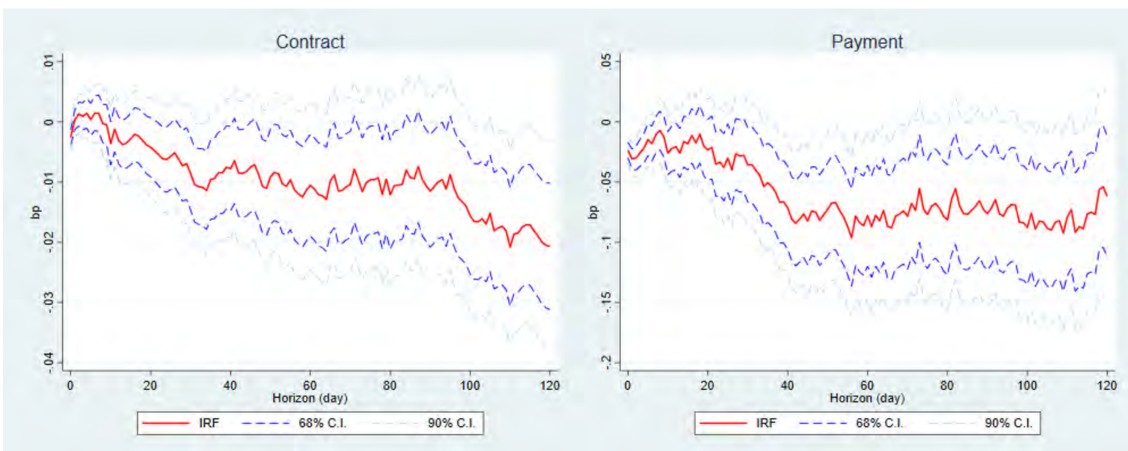
Note: This figure shows the impulse response of the price level using the daily online price index after controlling for 20 lags of the nominal effective exchange rate and crude oil prices. The left panel shows the response to a unit shock to the DoD contract; the right panel shows the response to a unit shock to treasury payments. The dashed lines denote 68% and 90% confidence intervals. The estimation sample is from December 1, 2008, to March 28, 2014.

Figure C.7. Price response to government spending shocks: excluding the Great Recession



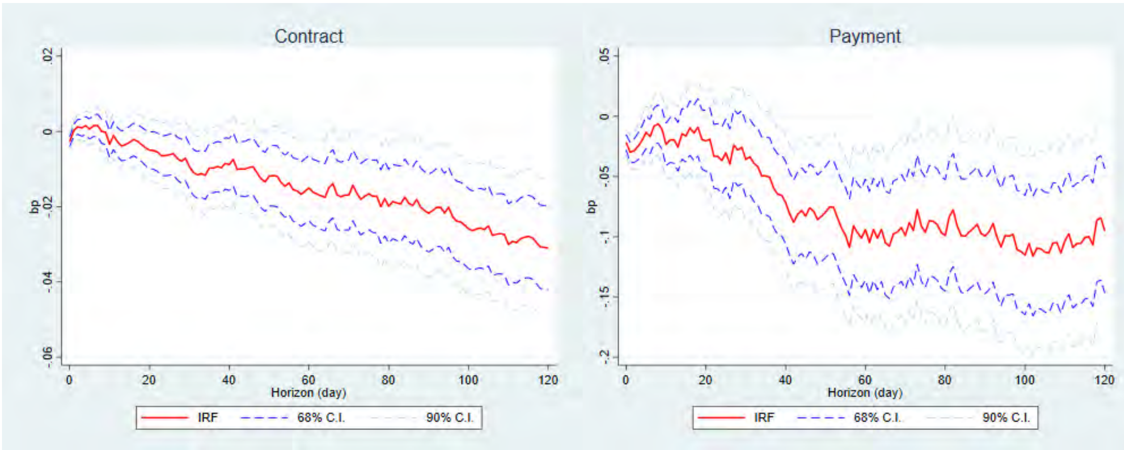
Note: This figure shows the impulse response of the price level using the daily online price index after dropping the Great Recession period (2008-09) from the estimation. The left panel shows the response to a unit shock to the DoD contract; the right panel shows the response to a unit shock to treasury payments. The dashed lines denote 68% and 90% confidence intervals. The estimation sample is from January 1, 2010, to March 28, 2014.

Figure C.8. Price response to government spending shocks: controlling for the ECI Index



Note: This figure shows the impulse response of the price level using the daily online price index after controlling for 20 lags of the Economic Confidence Index (ECI). The left panel shows the response to a unit shock to the DoD contract; the right panel shows the response to a unit shock to treasury payments. The dashed lines denote 68% and 90% confidence intervals. The estimation sample is from December 1, 2008, to March 28, 2014.

Figure C.9. Price response to government spending shocks: controlling for the EPU Index

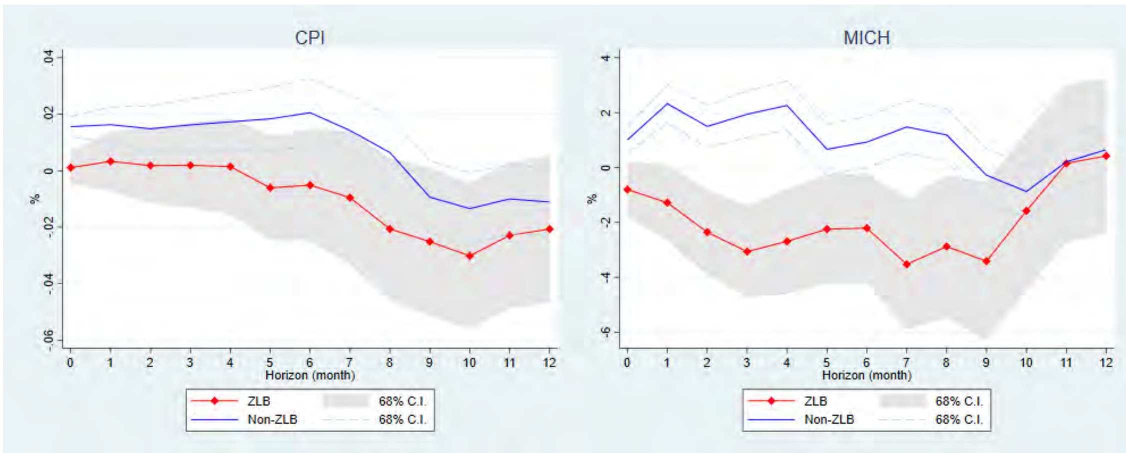


Note: This figure shows the impulse response of the price level using the daily online price index after controlling for 20 lags of the Economic Policy Uncertainty Index (EPU Index). The left panel shows the response to a unit shock to the DoD contract; the right panel shows the response to a unit shock to treasury payments. The dashed lines denote 68% and 90% confidence intervals. The estimation sample is from December 1, 2008, to March 28, 2014.

Figure C.10. State-dependent response to government spending shocks: implied ZLB probability

Note: This figure shows the state-dependent impulse response of the four variables of interest (the exchange rate, price level, ex-post real interest rate, and business conditions) to a unit shock to treasury payments. The red line illustrates the impulse response at the ZLB; the black line denotes the response during normal times. The dashed lines and the shaded area denote 68% confidence intervals. The estimation sample is from July 1, 2008, to April 13, 2018.

Figure C.11. State-dependent response to government spending shocks using monthly data: excluding the post-ZLB period



Note: This figure shows the state-dependent impulse response of prices and consumer inflation expectations to a unit shock in defense spending at a monthly frequency. The red diamond line illustrates the impulse response at the ZLB, and the blue line denotes the response during normal times. The dashed lines and the shaded area denote 68% confidence intervals. The estimation sample is from 1996M1 to 2015M12.