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

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**Abstract**

Are government spending shocks inflationary at the zero lower bound (ZLB)? Despite the ZLB's importance in amplifying a government spending multiplier, empirical evidence has not provided a clear answer to this question. Exploiting newly constructed high-frequency data on both government spending and the price index of the U.S. economy, we identify government spending shocks with standard timing restrictions when using low-frequency data. Applying local projections to the daily data, we find that prices decline persistently in response to a positive government spending shock at the ZLB, whereas they rise during normal times. Our finding is difficult to reconcile with the predictions of standard New Keynesian models, which typically indicate an increase in inflation following fiscal expansion. Instead, our result demonstrates that the binding ZLB is unlikely to produce a larger fiscal multiplier via inflation.

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**Keywords**: Zero lower bound; Government spending; Online price index; High-frequency data; New Keynesian model; COVID-19

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# I. Introduction

Are government spending shocks inflationary? Despite the rapid progress in identifying these shocks and understanding their macroeconomic effects (e.g., Blanchard and Perotti, 2002; Mountford and Uhlig, 2009; Auerbach and Gorodnichenko, 2012; Ramey and Zubairy, 2018), the literature has not reached a consensus on this matter. For example, Jørgensen and Ravn's (2018) review noted that almost equal numbers of studies have found disinflationary (or deflationary), inflationary, and null (insignificant) responses to government spending shocks.[1] The conventional wisdom is that increases in government spending are inflationary via the positive aggregate demand effect. This idea plays a crucial role in transmitting fiscal policy shocks in many theoretical models, including textbook New Keynesian models.

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; Woodford, 2011).[2] However, related research has been greatly constrained in this context because only a handful of low-frequency observations are available when the economy is at the ZLB (2009–2015). Although alternative approaches have been adopted to resolve this constraint, a small number of observations do not allow for sufficient statistical power to obtain a definite answer to the question.[3]

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[1] See Jørgensen and Ravn (2018) for a comprehensive review of empirical studies on the price response to government spending shocks in the U.S. economy.

[2] Under nominal rigidities, the upward shift in its 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.

[3] To circumvent the lack of sufficient time-series data in studying the effect of government spending shocks at the ZLB, some authors have estimated the time-varying parameter model (Klein and Linnemann, 2019). One exception is studies on the Japanese economy, where the chronic ZLB since the 1990s allow for a standard time-series analysis (Miyamoto et al., 2018).

We circumvent this challenge in identifying a causal relationship between government spending and inflation by exploiting the high-frequency (daily) data on 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] Moreover, online prices provide additional insights because price stickiness is less likely to play an important role in online markets than in traditional brick-and-mortar stores (Gorodnichenko et al., 2018).

We estimate the effect of government spending using local projections as in Jordà (2005) and Auerbach and Gorodnichenko (2016) and confirm the main finding of Auerbach and Gorodnichenko (2016) that the U.S. dollar appreciation in response to fiscal expansion still holds in the binding ZLB subsample. Importantly, we find robust evidence that prices decline significantly and persistently after a positive government spending shock. Thus, to the extent that the high-frequency data used in this study provide a more reliable identification of a fiscal shock, our finding contributes to settling the so-called "fiscal price puzzle" examined by Jørgensen and Ravn (2018).

We further find that inflation expectations over the medium to long term—measured by daily financial market data—decline in response to government spending shocks. Therefore, both ex-ante and ex-post real interest rates increase after positive government spending shocks. However, when we incorporate additional data from outside the ZLB period, we find that the same shock becomes inflationary and results in a decline in the real interest rate. From a theoretical perspective, it is puzzling that inflation and the real interest rate switch their signs when the economy is no longer constrained at the ZLB. We expect a less inflationary response when active monetary policy

[4] An alternative approach is using inflation expectations extracted from financial market data, readily available at a high frequency. However, as explained in Gürkaynak et al. (2010), this so-called "break-even" inflation measure can be affected by inflation risk premium or liquidity premium, resulting in a distorted measure of inflation expectations. We use a break-even inflation measure for robustness checks.

is allowed. Overall, our findings suggest that the stimulating effect of fiscal expansion at the ZLB is unlikely to operate via the inflation channel, as posited by many theoretical studies.

Through the open economy perspective, the deflationary effect of fiscal expansion might be induced by a decline in import prices via the nominal appreciation of the U.S. dollar. Then, the indirect effect on inflation via appreciation can dominate the direct demand effect of fiscal expansion. However, accounting for the open economy nature (by controlling for fluctuations in the nominal effective exchange rate and oil prices), which hardly affects the estimated deflationary response to the spending shock, makes our findings even more puzzling.

The remainder of the paper is organized as follows. Section II illustrates the effect of a government spending shock on inflation during the ZLB using a textbook New Keynesian model. In Section III, we introduce novel daily data on government spending and the price index, present the main findings, and provide a series of robustness checks. Section IV discusses how the empirical findings can be potentially reconciled with recently developed theoretical models and concludes.

## II. Simple Analytical Illustration

Using a simplified theoretical framework, we illustrate how the binding ZLB strengthens the inflationary response to government spending shocks, further stimulating consumption and output. 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

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

$$\pi_t = \beta E_t \pi_{t+1} + \kappa mc_t, \tag{2}$$

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

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

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.[5] Substituting Equations (3) and (4) into Equation (2), we have

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

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

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

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

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

Given Equations (1), (5), and (6) and the endogenous variables $c_t$, $i_t$, and $\pi_t$, 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

[5] As in Dupor and Li (2015), Equations (1) to (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.

policy. Following Boivin and Giannoni (2006) and Dupor and Li (2015), we only focus on the bubble-free equilibrium. Regardless of monetary policy, inflation and consumption in equilibrium are given by

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

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

where $\Theta = \frac{\sigma^{-1}\kappa(\sigma+\nu(1-s))(\psi-1)-\beta-1}{\beta}$. It can be clearly seen that $\Lambda = \frac{\kappa s\nu}{1-\beta\rho} > 0$ when $\psi = 1$. 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 $\Lambda$, we can easily confirm that $\Omega = 0$. Government spending shocks do not crowd out nor crowd in private consumption when $\psi$ equals one. For a reasonable value of $\psi$, 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. As $\psi$ only affects $\Lambda$ via changes in $\Theta$, 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 taken from Dupor and Li (2015) plots the equilibrium impact responses of inflation and consumption to a government spending shock under active and passive monetary policy, depending on the value of $\psi$.

This simple theoretical illustration clarifies the crucial role of inflation in characterizing the transmission channel of government spending at the ZLB. Equipped with a novel dataset spanning the ZLB at a daily frequency (2,460 observations), we now have enough statistical power to test the relevance of this theoretical channel.

# III. Empirical Analysis

## A. Data

This section presents the two primary datasets available at a daily frequency: the government spending and price index series. 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, iii) has a long time series, iv) takes a large domestic component, and v) is a major source of variation in government spending. Following Auerbach and Gorodnichenko (2016), we use the novel framework introduced by De Livera et al. (2011) to deseasonalize and detrend both series, 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 for timing government spending shocks and their responses. While these data series are mostly available throughout the ZLB, we 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 A.1 in the appendix plots both series at a daily frequency.

Second, we obtain the daily OPI from Cavallo and Rigobon (2016), calculated using price data from numerous websites. While they 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 consumer price index (CPI) and closely tracks fluctuations in the CPI during the sample period at a higher frequency (see Figure A.2 in the appendix). Moreover, new and disappearing products are easily detected and reflected in the index as the data collected are comprehensive. However, the daily OPI is available only from July 2008, which is chosen as the starting period of our empirical analysis.

Other variables used in the analysis include 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 daily, 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)-year maturity for the medium (long)-term interest rates. These variables are plotted in Figure A.3 in the appendix.

## B. Local projection method

We now briefly describe the main empirical framework used in the analysis. We employ Jórda's (2005) methodology for estimating the response of various macroeconomic and financial variables to government spending shocks. The local projection method was recently advocated by Auerbach and Gorodnichencko (2016) and Ramey and Zubairy (2018), among others, as a flexible alternative to VAR specifications without imposing the pattern generated by structural VARs. We iteratively estimate the following regression to calculate Jórda's impulse response function:

$$y_{t+h} - y_{t-1} = \alpha_h + \beta_h shock_t + \Phi_h(L)X_t + \varepsilon_{t+h},\ for\ h = 0, 1, 2, \cdots, \tag{10}$$

where $y_t$ is the dependent variable; our interest is its response. $shock_t$ is the daily government spending shock; $\Phi_h(L)$ is a lag polynomial; and $X_t$ is a set of control variables, including the lags of the dependent variable and the shock variable.

This specification also corresponds to the standard VAR approach in identifying a government spending shock (Blanchard and Perotti, 2002), where government spending appears before other macroeconomic variables in the Cholesky decomposition. This order reflects the identifying assumption that a 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 likely to hold. Thus, following Auerbach and Gorodnichencko (2016), we include 20 lags.

In Equation (10), $\beta_h$ shows the response of the dependent variable $h$ days after the shock. Therefore, a series of $\beta_h$ illustrates the dependent variable's impulse response function to a shock. In our analysis, $\beta_h$ indicates the cumulative impact of military spending changes on the dependent variable after $h$ days. One potential problem in Jórda's method is the serial correlation of the error terms, and in our case, the extent of persistence of the dependent variable. We adopt the Newey-West (1987) heteroskedasticity and autocorrelation-corrected standard errors to address this challenge.

*State-dependent local projections.* While our baseline analysis focuses on the period characterized by the binding ZLB based on the availability of daily data, we extend our analysis by incorporating more recent data on the second measure of government spending (i.e., payments to defense contractors). Local projections are particularly useful in this context. The above model can be conveniently transformed into a state-dependent model, which allows for testing, within a single equation framework, 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 and has been used in ZLB studies (e.g., 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:

$$y_{t+h} - y_{t-1} = I_{t-1}[\alpha_{Z,h} + \beta_{Z,h} shock_t + \Phi_{Z,h}(L)X_t] + \\ (1 - I_{t-1})[\alpha_{N,h} + \beta_{N,h} shock_t + \Phi_{N,h}(L)X_t] + \varepsilon_{t+h}. \quad (11)$$

Here, we allow variation in coefficients according to whether the ZLB is binding to acquire a state-dependent impulse response function. Specifically, the first part of Equation (11) 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, a series of $\beta_{Z,h}$ for $h = 1, 2, \ldots$ denotes the impulse response to government spending shocks at the ZLB, whereas a series of $\beta_{N,h}$ describes the same during normal times.

### C. Main results

*Response of the nominal exchange rate.* To check whether the main finding of Auerbach and Gorodnichencko (2016) still holds in our subsample at the ZLB, we first plot the response of the nominal effective exchange rate to a one standard deviation shock in 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 the 68% and 90% confidence bands. The baseline analysis is from July 1, 2008 to March 28, 2014. The starting period is based on the availability of daily OPI data, while the ending period is constrained by the availability of daily government spending data.

As shown in Panel A of Figure 2, 20 business days (corresponding to about a one-month response) after the announced spending, the dollar appreciates by 0.15%, consistent with the original finding of Auerbach and Gorodnichencko (2016) who used data between 1994 and 2014. Additionally, in Panel B, we present the daily responses of the exchange rate to actual spending (daily payments to defense contractors) to demonstrate the difference between announced and actual spending shocks. Compared to Auerbach and Gorodnichencko (2016), we observe a much stronger appreciation following the actual spending shock.

While this finding does not align with that 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), it is in line with the prediction of standard open economy models, such as the Mundell–Fleming model, as well as more recent DSGE models (e.g., Erceg et al., 2010). Moreover, to the extent that monetary accommodation often followed fiscal expansion, the stronger appreciation of USD at the ZLB period can be understood by the absence of monetary easing. As we do not rely on dubious identification restrictions, especially when fast-moving financial variables such as the exchange rate are involved, we view the nominal appreciation following fiscal expansion as a credible description of the U.S. economy during the recent ZLB.

*Response of prices.* Figure 3 summarizes the main finding of this study: the response of the daily log OPI to government spending shocks during the ZLB. Prices decline persistently after fiscal expansion, regardless of whether government spending shocks are identified by announcements (Panel A) or actual payments (Panel B). The inflation response is marginally statistically significant for announcements and strongly statistically significant for payments. The effects are also economically significant in both cases. Three months later, prices decline by 0.023% in response to the announcement shock and by 0.052% in response to the actual payment shock. The magnitude of the effects is translated into annualized inflation of about -0.1% for the announcement shock (about -0.2% for the actual payment shock).

The deflationary response to government spending shocks in Figure 3 identified via the newly constructed daily data during the ZLB contributes to settling the fiscal price puzzle. Despite a straightforward theoretical prediction of the standard New Keynesian model, empirical studies have often found contrasting evidence on the sign of the effect of government spending shocks on inflation.[6] To the extent that employing high-frequency data alleviates the endogeneity issue in

[6] For example, Edelberg et al. (1999), Caldara and Kamps (2008), and Ben Zeev and Pappa (2017) found an inflationary response to a government spending shock, whereas Fatás and Mihov (2001), Mountford and Uhlig (2009), Jørgensen and Ravn (2018), and d'Alessandro et al. (2019) found a disinflationary response to the same shock.

identifying a causal relationship between macroeconomic variables, the novel finding from daily data helps solve the puzzle and disciplines the theoretical model. At the same time, it casts doubt on the well-known theoretical prediction that government spending shocks are more expansionary at the ZLB via the inflation channel (e.g., Christiano et al., 2011; Woodford, 2011), thereby providing a potential explanation for Ramey and Zubairy's (2018) main finding that the size of the government spending multiplier is not greater at the ZLB.

*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 actual 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).

The left panel corresponds to the five-year-ahead inflation expectations and the right panel to the twenty-year-ahead expectations. Although the results are less clear-cut than in the OPI case, they highlight a decline in inflation expectations, especially for the five-year-ahead period. The finding that the expected disinflationary effect is weaker in the long term is consistent with the notion that long-run inflation expectations were still anchored during the ZLB (Ascari and Sbordone, 2014; Choi et al., 2018a). However, caution is required when interpreting these results, because the variation in TIPS yields can be affected by 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).[7] This explains why we prefer using the realized inflation response using the OPI, which is free of such confounding factors.

[7] The direction of bias created from inflation risk premium or liquidity premium is theoretically unclear,

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

The first panel of Figure 5 shows that the response of the realized interest rate is generally insignificant, implying that the conditional response of the nominal interest rate is not necessarily zero and counteracts a decline in realized inflation according to the Taylor rule. 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 do not observe a decline in the real interest rate as predicted by standard New Keynesian models, regardless of how it is measured.

*Additional exercises covering the non-ZLB period.* While the theoretical prediction of a standard New Keynesian model provides a definite answer regarding the inflation response to government spending shocks at the ZLB, the response during normal times is unclear a priori. It depends on how responsive the monetary policy is under the Taylor rule. Therefore, we use additional observations after the Federal Reserve lifted its policy rate in December 2015 to investigate whether the inflation response differs between normal times and the ZLB period. The following analysis is somewhat constrained by data availability, as we can extend the payment series only. The ending period (April 2018) is chosen based on the availability of the daily OPI series.

As a first exercise, we analyze the effects of the shock to payments to defense contractors using the observations from the non-ZLB period only (January 2016 to April 2018). Figure 6 presents the responses to the payment shock of the nominal effective exchange rate, Federal Funds Rate, price level, five-year-ahead inflation expectations, actual real interest rate, and expected real interest rate (five year ahead).

We find different responses for every variable. First, unlike the response during the ZLB period, the nominal exchange rate does not appreciate in the short run and exhibits delayed appreciation. Second, the nominal interest rate rises immediately and declines after a month. However, one cannot detect a robust pattern in the behavior of the exchange rate and interest rate, probably because of the short sample period. Nevertheless, the inflation response is striking. Unlike during the ZLB, the response becomes inflationary and highly statistically significant for the first two months. The response of inflation expectations is less clear-cut but points toward a mild increase. Therefore, we find a decline in the real interest rates, although it is not statistically significant.

However, this subsample analysis might suffer from insufficient statistical power despite the use of daily data. Thus, as a second exercise, we exploit the state-dependent local projection method, enhancing estimation efficiency by using an effectively larger sample to address this issue. The effects of the government spending shock between normal times and the ZLB period in Figure 7 largely confirm the results in Figure 6. Outside the ZLB period, we find a strong inflationary response and a significant decline in the real interest rate. However, the responses of other variables are not systematically different between the two states.

From a theoretical perspective, it is puzzling that inflation and the real interest rate switch their signs when the economy is no longer constrained at the ZLB. We expect a less inflationary response when active monetary policy is allowed. However, considering the risk-tolerating stance of the U.S. monetary policy since the Great Recession, the results presented in Figures 5 and 6 are aligned with the policy in practice. Although we do not account for the distinct inflation response between normal times and the ZLB period, this finding further supports the main finding of the study that the binding ZLB is unlikely to produce a larger fiscal multiplier via inflation.

*Robustness checks.* We provide several robustness checks for the main finding that government spending shocks are deflationary at the ZLB. First, given the recent evidence on the degree of price stickiness (i.e., frequency of price changes) estimated from online price data (Gorodnichenko and Talavera, 2017; Cavallo, 2018), we choose three months as a baseline estimation horizon. However, considering the price stickiness parameters estimated through the class of the New Keynesian model (e.g., Eichenbaum et al., 2014), the three months in the baseline analysis may still be insufficient to describe the full dynamic inflation response. Indeed, the baseline inflation response to the announcement shock (left panel in Figure 3) is statistically insignificant at the 90% confidence level. Thus, we extend the estimation horizon up to 120 business days (about six months). In Figure A.4 in the appendix, we confirm that the deflationary response is persistent, and the response to the announcement shock becomes statistically significant at the 90% level five months after the shock.

Second, unlike most studies that identified 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 a robust appreciation using daily fiscal spending data. We further confirm that this finding still holds when limiting the analysis to the ZLB. 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.

We plot the response of prices to government spending shocks after controlling for 20 lags of the nominal effective exchange rate. Figure A.5 in the appendix shows that controlling for the exchange rate movements hardly affects the inflation response to the government spending shock.[8] The inability of the nominal exchange movements to account for the documented response is

[8] Controlling for the growth of the nominal effective exchange rate leads to the same result.

consistent with the lower exchange rate pass-through documented for the U.S. (Campa and Goldberg, 2005) and for the average good priced in U.S. dollars among U.S. imports (Gopinath et al., 2010).[9]

Third, given the large open economy nature of the U.S. economy, it is possible that domestic fiscal expansion influences commodity prices such as oil prices worldwide, feeding back into U.S. consumer prices. Despite the decreasing oil price pass-through over time (Chen, 2009; Choi et al., 2018b), this transmission channel is distinct from the exchange rate pass-through and is worth investigating. We, therefore, control for 20 lags of the log of crude oil prices (West Texas Intermediate) in addition to the nominal effective exchange rate. Figure A.6 in the appendix shows that this additional control hardly changes the inflation response to the government spending shock, suggesting that incorporating the open economy nature into the estimation framework cannot fully account for the deflationary response to the government spending shock at the ZLB.

Lastly, given the ample theoretical and empirical evidence on the asymmetric effects of government spending shocks on the output between expansions and recessions (Auerbach and Gorodnichenko, 2012; Biolsi, 2017), the deflationary response 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 substantial share of the total sample used in the estimation. To test this possibility, we re-estimate the inflation response by using the observations since 2010. Figure A.7 in the appendix confirms that the behavior does not simply drive the deflationary response to the government spending shock during the Great Recession.

## IV. Discussion and Concluding Remark

The empirical evidence presented in this paper is inconsistent with the predictions of a standard New Keynesian model. The lack of inflationary response to government spending shocks at the recent ZLB of the U.S. economy corroborates Dupor and Li's (2015) finding. They found that

[9] 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.

the inflation response during the recent ZLB period (or during the earlier period characterized by passive monetary policy) does not align with the prediction of the textbook New Keynesian model. Furthermore, Garín et al. (2019), using a local projection, found that the effects of supply shocks on output and inflation at the ZLB were inconsistent with the predictions of a standard New Keynesian model.

In both studies, the inflation channel plays an important role in determining the size of the fiscal multiplier at the ZLB. Thus, robust evidence on the deflationary response to the government spending shock at the ZLB must be considered in the design of theoretical models to analyze the interaction of fiscal policy and the ZLB. Instead of proposing a new theoretical framework, we discuss relevant recent works that, in our view, offer promising extensions to the basic New Keynesian framework that might help make the model more consistent with our empirical findings and resolve the fiscal price puzzle.

A promising avenue is introducing a self-fulfilling state of confidence that creates a liquidity trap (Mertens and Ravn, 2014; Brendon et al., 2020). In this class of models, higher government spending has deflationary effects that reduce the spending multiplier in a confidence-driven liquidity trap when the ZLB is binding. In contrast, in a fundamental liquidity trap, increased government spending is inflationary and can have very large expansionary effects.[10] Thus, according to this model, the deflationary response and the fall in the real interest rate following a rise in government spending implies that the recent ZLB in the U.S. economy is better characterized by the confidence-driven liquidity trap.

Another promising variation is to introduce deep habit formation (Zubairy, 2014) or variable technology utilization (Jørgensen and Ravn, 2018) into an otherwise standard medium-scale New Keynesian model, assume monetary policy inertia at the ZLB (Hills and Nakata, 2018), or consider

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[10] Mertens and Ravn (2014) showed that, under the assumption that fiscal or unconventional monetary policies do not shorten the duration of the liquidity trap, the impact of government spending is sharply different between the fundamental and the confidence-driven liquidity trap.

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 the propagation of fiscal shocks. Since markups are countercyclical, a government spending shock can lead to a decline in inflation. Jørgensen and Ravn (2018) show that variable technology utilization allows firms to accommodate increased demand by adopting new technology into the production process. The resulting increase in measured productivity leads to a decline in prices.

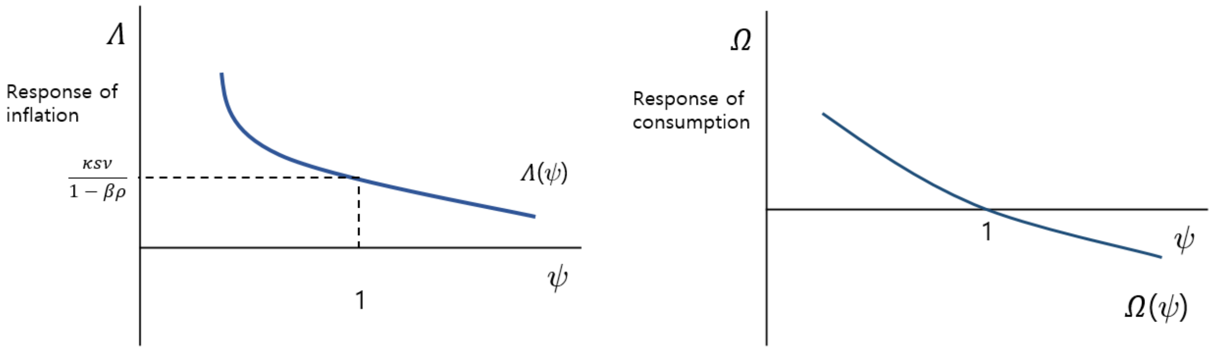
Hills and Nakata (2018) show that the economy with policy inertia can bring the prediction of the New Keynesian model more closely to our empirical findings. Policy inertia reduces the government spending multiplier by reducing the effects of government spending shocks on expected inflation. Ercolani 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.

Our work fits broadly into a growing literature that empirically tests predictions of the textbook New Keynesian model when the ZLB is binding. However, as our empirical results are inconsistent with the predictions of the textbook model, caution is required when using our model to make predictions about the economic consequences of fiscal policies at the binding ZLB. Further research into other alternative model specifications is desirable.

Lastly, our novel findings 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 fallen into a ZLB period since March 2020, it does not necessarily guarantee a larger fiscal multiplier from fiscal expansion, according to our estimates. Thus, more careful analysis, possibly using a real-time tracker, should be conducted before drawing any pre-emptive justification of fiscal policy effectiveness.

## Figures and tables

Figure 1. Equilibrium impact responses of inflation and consumption to a government spending shock under active and passive monetary policy rules

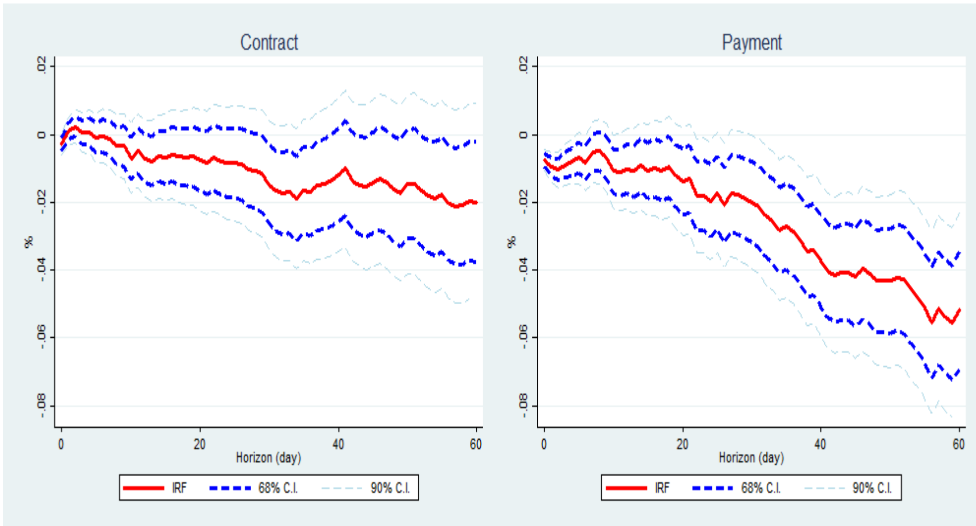



Note: This graph plots the equilibrium impact responses of inflation (left) and consumption (right) to a government spending shock in terms of the parameter $\psi$.

Figure 2. Nominal exchange rate response to government spending shocks

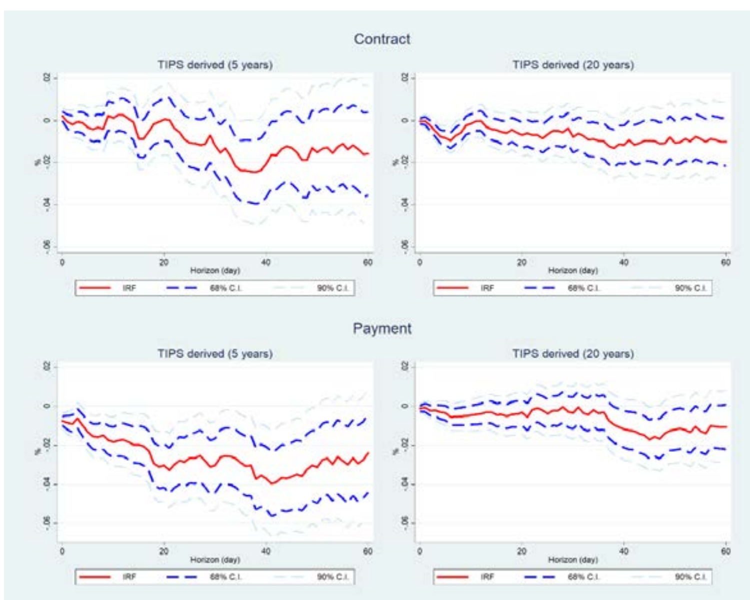

Note: This figure shows the impulse response of the nominal effective exchange rate, using the trade-weighted exchange rate of the dollar. An increase denotes the appreciation of the dollar vis-à-vis its trading partners. The left panel shows the response to one standard deviation shock of the DoD contract, and the right panel shows the response to one standard deviation change in treasury payment. The dashed lines denote 68% and 90% confidence intervals. The estimation sample is from July 1, 2008, to March 28, 2014.

Figure 3. Inflation response to government spending shocks



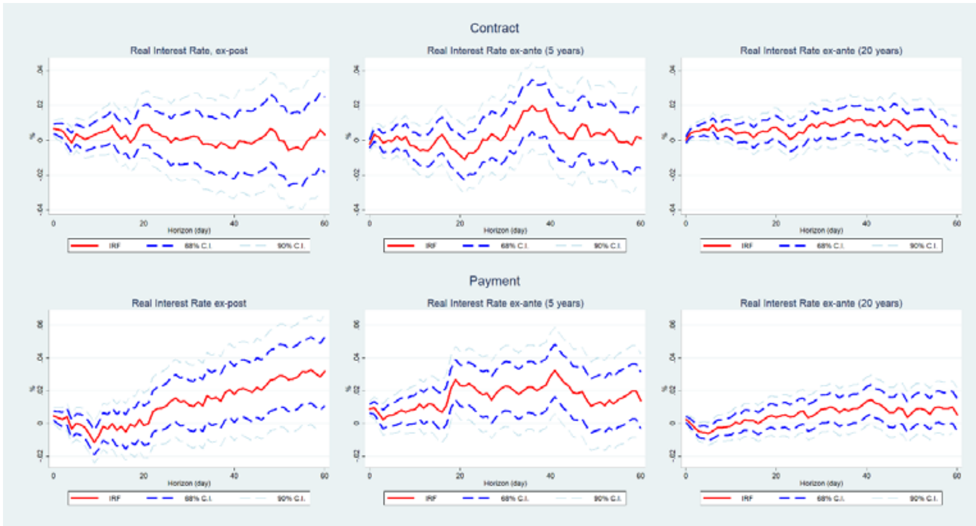

Note: This figure shows the impulse response of the price level using the daily online price index. The left panel shows the response to one standard deviation shock of the DOD contract, and the right panel shows the response to one standard deviation change in treasury payment. The dashed lines denote 68% and 90% confidence intervals. The estimation sample is from July 1, 2008, to March 28, 2014.

Figure 4. Inflation expectation response to government spending shocks




Note: This figure shows the impulse response of the inflation expectation derived by subtracting yields of the TIPS with a maturity of 5 years (left) and 20 years (right) from treasury yields of the corresponding maturities. The left panel shows the response to one standard deviation change in the DoD contract, and the right panel shows the response to one standard deviation change in treasury payment. The dashed lines denote 68% and 90% confidence intervals. The estimation sample is from July 1, 2008, to March 28, 2014.

Figure 5. Real interest rate response to government spending shocks

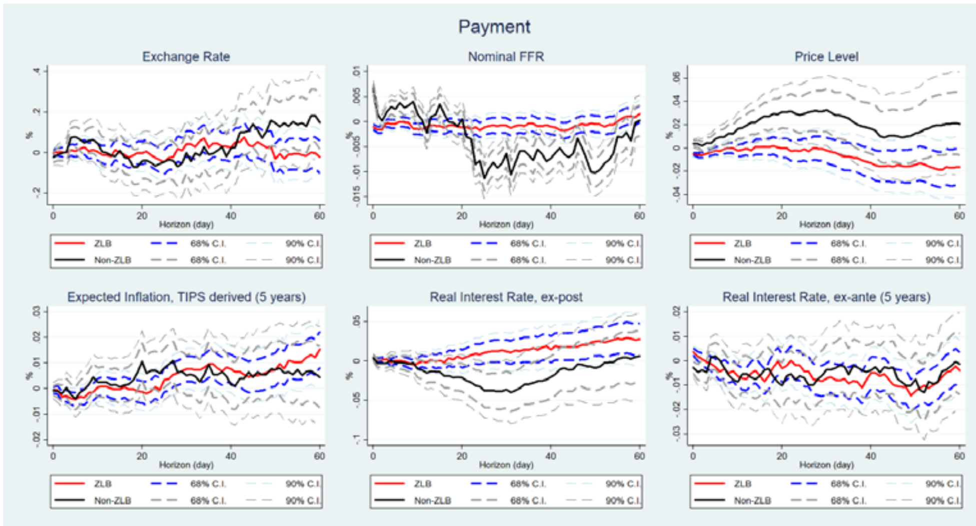



Note: This figure shows the impulse response of different types of real interest rates: ex-post real interest rate using the difference between effective Federal Funds rate and realized OPI inflation (left), TIPS with 5- and 20-year maturities (center, right), The upper panels show the response to one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

Figure 6. Response to government spending shocks: normal times (January 2016 – April 2018)


Note: This figure shows the impulse response of the six variables of interest (nominal interest rate, nominal effective Federal Funds rate, price level, expected inflation, ex-post and ex-ante real interest rate) to one standard deviation change in treasury payment, but using subsample that covers normal times. The dashed lines denote 68% and 90% confidence intervals. The estimation sample is from January 4, 2016, to April 13, 2018.

Figure 7. State-dependent response to government spending shocks: ZLB vs. non-ZLB




Note: This figure shows the state-dependent impulse response of the six variables of interest (nominal interest rate, nominal effective Federal Funds rate, price level, expected inflation, ex-post and ex-ante real interest rate) to one standard deviation change in treasury payment. The red line illustrates the impulse response at the ZLB, and the black line denotes the response during normal times. The dashed lines denote 68% and 90% confidence intervals. The estimation sample is from July 1, 2008, to April 13, 2018.

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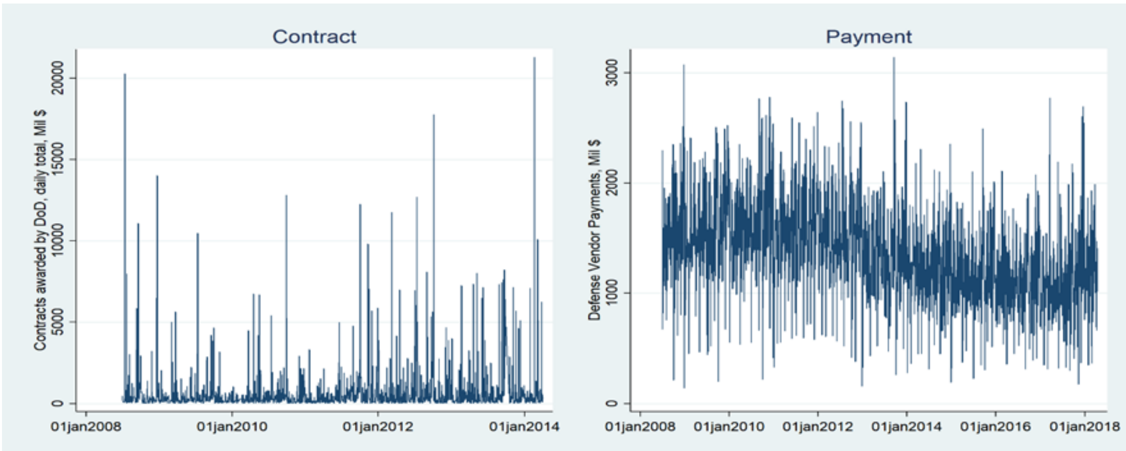
# Appendix

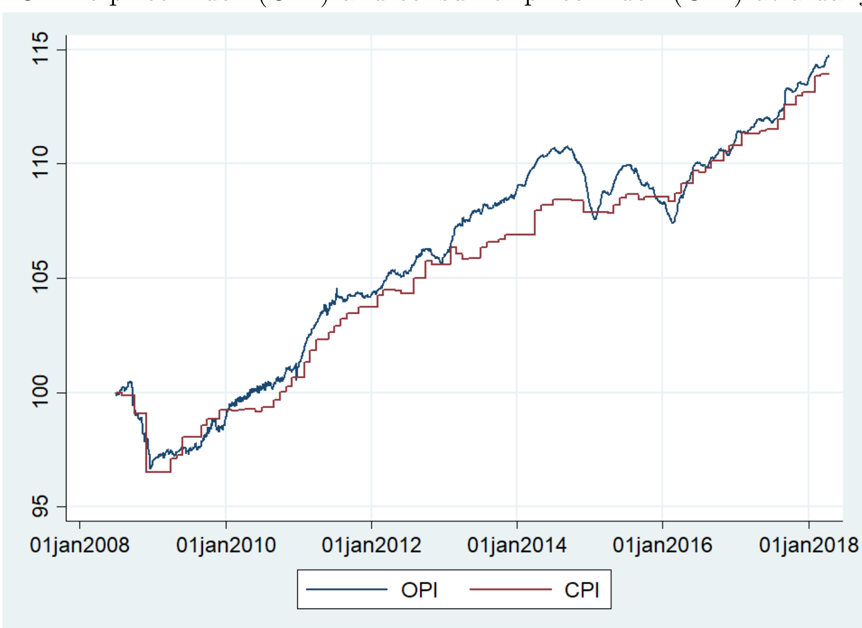
## A. Additional figures and tables

Figure A.1. Daily measure of government spending (left panel: announced volume of contracts, right panel: payments to defense contracts)



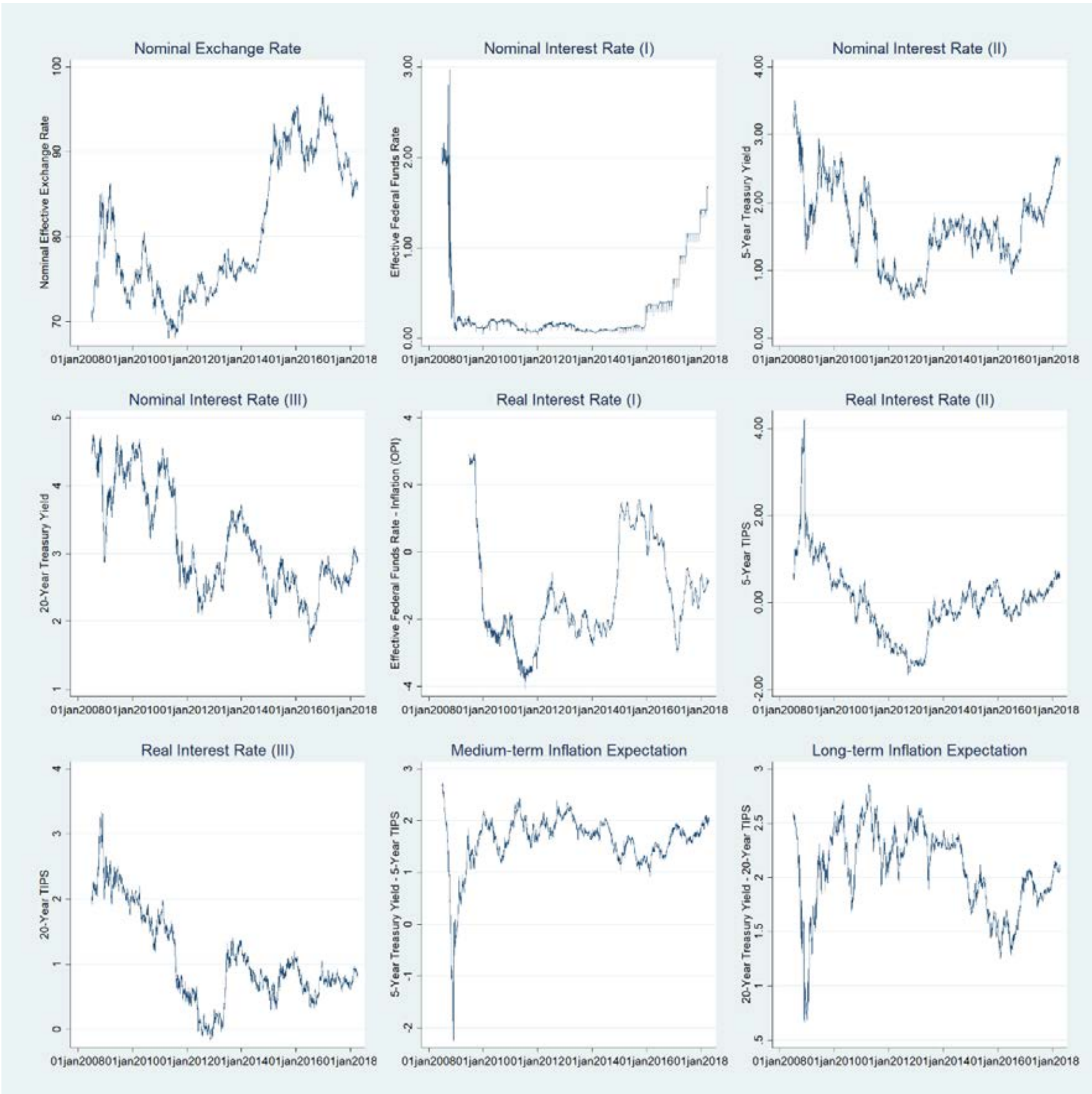

Note: This figure plots two daily series of government spending constructed by Auerbach and Gorodnichenko (2016). The left panel shows the first series—announced volume of contracts awarded daily by DoD—that covers the sample period from July 1, 2008, to March 28, 2014, and the right panel presents the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

Figure A.2. Online price index (OPI) and consumer price index (CPI) at a daily frequency



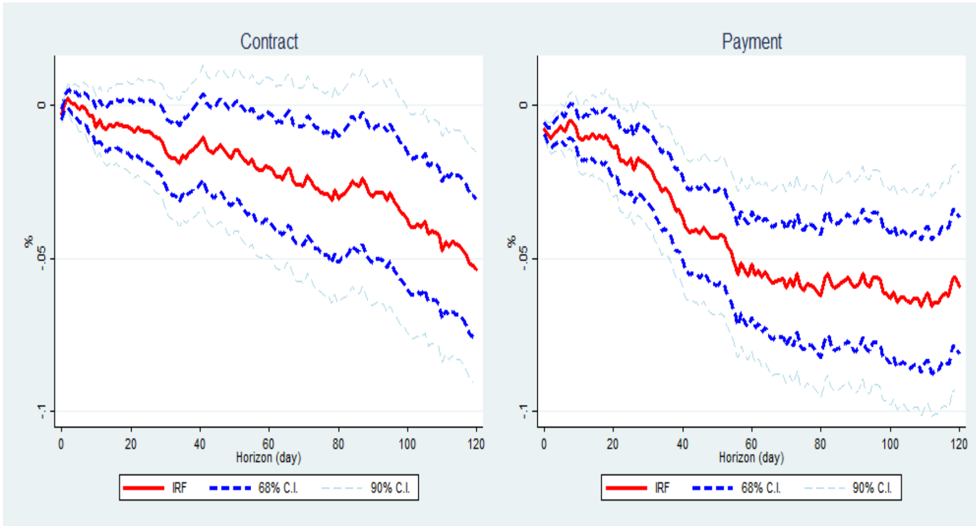

Note: This figure plots the daily time series of the U.S. daily online price index and the consumer price index released by the Bureau of Labor Statistics for the sample period between July 1, 2008, and April 13, 2018. The indices are normalized by the first observation of each series.

Figure A.3. Evolution of the main variables used in the analysis



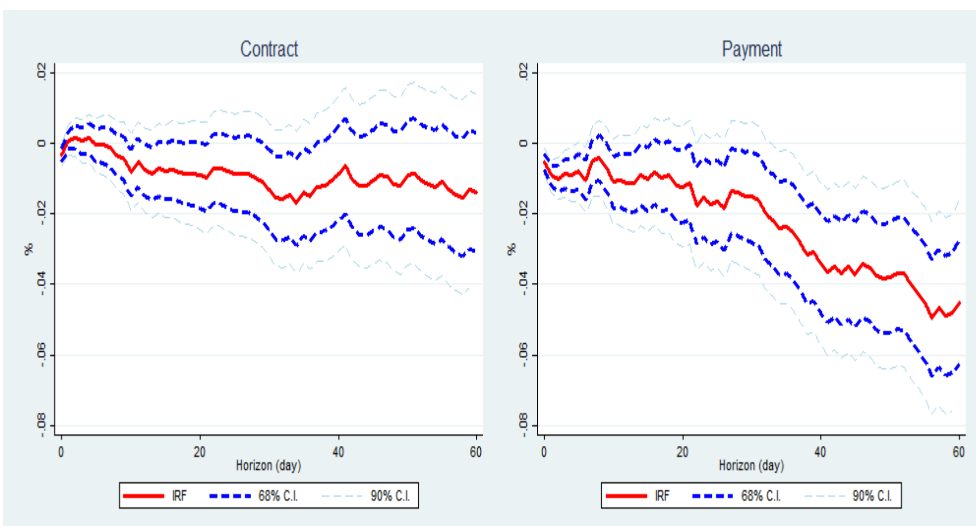

Note: This figure presents time series graphs for nine variables of our interest (nominal effective exchange rate, effective Federal Funds rate, 5-year Treasury yield, 20-year Treasury yield, ex-post and two ex-ante real interest rates, and two inflation expectation measures). The sample period is between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

Figure A.4. Inflation response to government spending shocks: 120-day horizon




Note: This figure shows the impulse response of the price level using the daily online price index. The left panel shows the response to one standard deviation change in the DoD contract, and the right panel shows the response to one standard deviation change in treasury payment. The dashed lines denote 68% and 90% confidence intervals. The estimation sample is from July 1, 2008, to March 28, 2014.

Figure A.5. Inflation response to government spending shocks: controlling for the nominal exchange rate

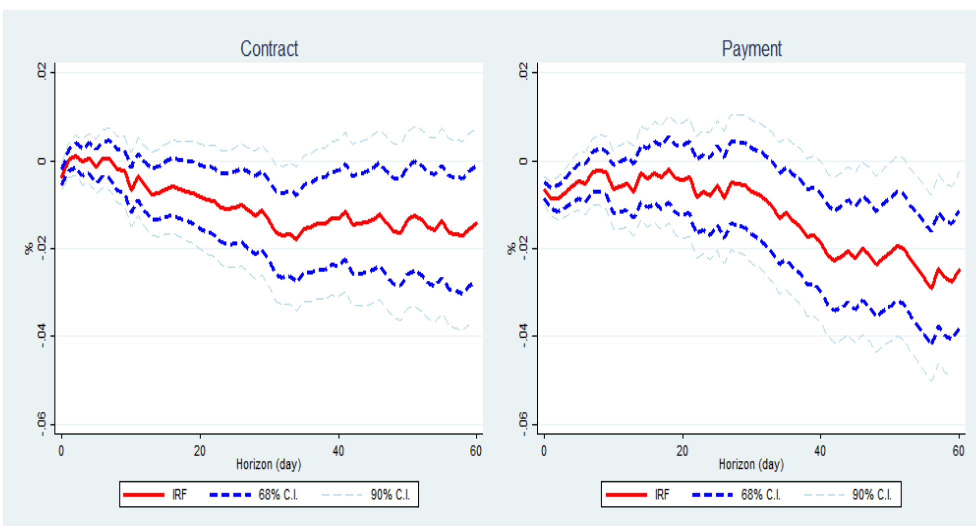



Note: This figure shows the impulse response of the price level using the daily online price index after controlling for 20 lags of the nominal effective exchange rate. The left panel shows the response to one standard deviation change in the DoD contract, and the right panel shows the response to one standard deviation change in treasury payment. The dashed lines denote 68% and 90% confidence intervals. The estimation sample is from July 1, 2008, to March 28, 2014.

Figure A.6. Inflation 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 one standard deviation change in the DoD contract, and the right panel shows the response to one standard deviation change in treasury payment. The dashed lines denote 68% and 90% confidence intervals. The estimation sample is from July 1, 2008, to March 28, 2014.

Figure A.7. Inflation 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 one standard deviation change in the DoD contract, and the right panel shows the response to one standard deviation change in treasury payment. The dashed lines denote 68% and 90% confidence intervals. The estimation sample is from January 1, 2010, to March 28, 2014.