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Three Essays on Monetary and Fiscal Policy

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To my family

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Three Essays on Monetary and Fiscal Policy

Abstract

Monetary and fiscal policies are two main tools to steer the economy. How they are or will be implemented affects the private sector's behavior and expectation about the future, thus the macroeconomic dynamics. In this thesis, I study the monetary and fiscal policies recently introduced in reality or documented empirically. Chapter 1 studies the nonlinear properties of average inflation targeting(AIT) and explores how those affect the fiscal multiplier. Chapter 2 estimates state-dependent fiscal multipliers. Instead of widely used states, such as business cycles or zero lower bound(ZLB) episodes, I estimate them conditional on the credit cycle. Chapter 3 investigates the effects of negative interest rate policy(NIRP) expectations on the fiscal multiplier.

Chapter 1 shows that it matters how to solve the model both with AIT and with an occasionally binding ZLB. When the model is solved based on the first-order perturbation method in a piecewise linear fashion, the social welfare increases as the averaging window lengthens, which is in line with the conventional wisdom. On the contrary, if the model is solved fully nonlinearly, the social welfare starts decreasing beyond the medium window length, in our baseline case, a 6-year window, while it rises steadily up to that threshold. With the longer window AIT, the agents expect a much looser policy when ZLB is binding, which results in less possibility of a future binding constraint through the high inflation expectations. This effect becomes stronger under a longer window AIT so that average inflation is higher than the target. For the monetary authority to meet the target, it raises rates in the longer window AIT, unlike the shorter window AIT. These opposite reactions increase social welfare up to a 6-year window but generate lower welfare beyond that. This property also affects the fiscal multipliers under AITs with different window lengths both outside the ZLB and at the ZLB.

Chapter 2 demonstrates that the credit data predict the government spending shocks identified without controlling for the credit variables. To circumvent this problem, the shocks are extracted with real credit data as well as conventional real variables. Using this new series of shocks, I provide new evidence on the effects of unexpected changes in government spending conditional on the credit cycle. The on-impact output multiplier is 1.85 in the credit recession and 0.92 outside the recession. Since the credit cycle is not much overlapped with the business cycle, the results seem not driven by business cycle dependency. In addition, the results are robust to alternative model specifications.

Finally, Chapter 3 finds that the fiscal multiplier decreases nonlinearly as the private sector anticipates the higher likelihood of NIRP more in the future. While the on-impact fiscal multiplier at the ZLB is 1.5 without any expectation about NIRP, it falls below 1 when the agents expect the economy to switch the NIRP in two quarters, on average. This result is not derived from the fact that the fiscal multiplier under NIRP is smaller than one. In fact, in the baseline simulation, it is still higher than the unity, 1.52. This shows that the possibility of NIRP (or, more broadly speaking, much looser policies) mitigates the size of the fiscal multiplier at the ZLB, and that effect is nontrivial.

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CHAPTER 1

Nonlinear property of Average Inflation Targeting(AIT) and its effect on Fiscal Multiplier

1.1. Introduction

The historical downward trend of real interest rates has imposed big challenges for monetary policy. As the possibility of binding zero lower bound(ZLB) constraint gets larger, the private sector has taken this likelihood into account in their decision making. Accordingly, inflation expectations has been adjusted downward and stayed below the target for prolonged periods. This is so called the deflationary bias, which was first documented by Adam and Billi (2007) and Nakov (2008)[1]. Among others, makeup strategies, especially the average inflation targeting(AIT), has drawn most attention from academics and practitioners to address this problem because of its less deviation from current inflation targeting(IT) and relatively easy transition from IT[2].

The existing literature has studied and showed outperformance of AIT over IT, and longer window AIT over shorter window AIT in terms of social welfare. Those results are derived from linear quadratic approach from normative literature(see, for example, Nessén and Vestin (2005) and Budianto et al. (2020)) or linearized model from positive literature(see, for example, Amano et al. (2020) and Coenen et al. (2021)). One thing to note regarding AIT is that a different window length might affect the private sector's expectation about the possibility of a binding ZLB in the future, which might also change the macroeconomic

[1]See also Bianchi et al. (2021) for a recent documentation of this stylized fact.
[2]In this regard, the central banks seem to cautious about adopting price level targeting. In addition, because of rare experience of it in the history, they appear to be reluctant to be the first who steps into the unchartered territory.

dynamics. However, those approaches fail to capture this feature because of certainty equivalence.

I show that the expectation effect arising from the window length is not trivial. By solving the model nonlinearly, I allow the solution of the model to capture the different expectation effects depending on the averaging window of AIT. Since the number of state variables increases as the averaging window gets longer, solving the model nonlinearly becomes not feasible with medium to longer window AITs. To circumvent this issue, I use an exponential moving average(EMA) instead of a simple moving average(SMA) following Budianto et al. (2020). While EMA reduces the number of state variables to one to represent any windows of AIT, it deviates from SMA which is widely assumed in the literature. As the window gets longer, though, EMA becomes similar to SMA.

To see how agents adjust expectations responding to the various policy rules, I compare the stochastic steady state(SSS) under each monetary policy rule. To that end, I conduct a quantitative welfare-based analysis with a standard New Keynesian(NK) model featuring an AIT as a form of simple monetary policy rule. I calibrate the model because rare experiences of AITs preclude estimation of structural parameters in the model, especially the coefficients of inflation or output responses in the policy rule. Following the literature, in my baseline parameterization, I set the coefficient of inflation response to the length of averaging window of AIT[3].

According to my baseline simulation, whereas social welfare increases with AITs whose averaging window is relatively short, it starts declining with the averaging window longer than 6 years. As the averaging window gets longer, the agents expect much looser policy when the ZLB is binding, which results in higher inflation expectations, thus less possibility and frequency of a binding constraint. This expectation effect lowers real interest rates at first so that output with the longer averaging window is high.

[3]This makes the volatilities of the policy rate comparable.

While this effect is not strong enough to remove deflationary bias with shorter averaging window AITs, average inflation gets higher than the target with longer averaging window AITs. For the monetary authority to meet the average inflation target, it lowers nominal interest rates in the shorter window AIT regimes, but raises the rates in the longer window AITs. These opposite reactions result in higher output as the window gets longer to 6 years, but generate lower output with more longer window AITs. Because the social welfare is closely related to the level of output, it does not increase monotonically as the averaging window gets longer, either.

What is important is that this result appears only when the model is solved nonlinearly. When the model is solved using first-order perturbation method in a piecewise linear fashion, as in the conventional wisdom, the social welfare with longer window AIT is higher than that with shorter window AIT. That is, it fails to capture the expectation effects from the different window length. Therefore, it is desirable to solve the model globally when one needs to compare various AITs.

This nonlinear property affects the fiscal multipliers under AIT compared to the case of IT both outside the ZLB and at the ZLB. The main channel through which the increase of government spending affects the economy is the heightened inflation expectation. Since the adoption and the window of AIT affect how the agents form their inflation expectations, the fiscal multiplier is also changed by those factors.

Outside the ZLB, the fiscal multiplier under AIT is smaller than that with IT. Because the agents expect higher-for-longer policy responding to the additional demand, the inflation rises less relative to IT case. Even though the real interest rates under AIT is lower than IT at impact, it increases more after a few periods because of accommodation of past inflation gains. This causes the output to increase less than IT case over the horizon. With longer window length, the real interest rates remained increasing for longer periods so that the fiscal multiplier falls.

At the ZLB, the multiplier under IT rarely changes compared to the outside ZLB case. This is because i) the flat Phillips curve attenuates the substitution effect by preventing the big rise of inflation expectation and ii) the persistent government spending shocks strengthen the wealth effect. Unlike the IT case, however, the multipliers under AITs are higher than outside the ZLB case. Despite the aforementioned two factors which prevent the rise of the fiscal multiplier, inflation expectations rise further because the agents expect the lower-for-longer policy to combat the negative shocks. This additional expectation channel under AIT raises the fiscal multiplier at the ZLB. It is noteworthy that these results are derived based on the empirically well-supported assumptions: flat Phillips curve[4] and persistent government spending shocks.

I perform several robustness checks. For the social welfare in SSS, I consider four variants: no habit, different coefficients of inflation and output responses in the policy rule and steep Phillips curve. For the fiscal multiplier I analyze the following cases: steep Phillips curve, output responses in the policy rule and less persistent government spending shocks.

My contribution to the literature are twofold. First, I explain why the longer window AITs could be worse off than shorter window AITs or IT. Nessén and Vestin (2005) showed that backward-looking components in the Phillips curve make this possible. My result does not require those parts. Instead, I show that it matters how to solve the model equipped with AIT and an occasionally binding ZLB constraint. Amano et al. (2020) is close to mine. They also use the NK with implementable AIT rule and find that the degree of history dependence is relatively low. Unlike them, my result is derived from the different strength of expectation effects depending on the window length, which only can be found with nonlinear solution method. Second, I study how the AIT affects the fiscal multiplier in the normal time and in the ZLB time, respectively. To my knowledge, I am the first to explore the interaction of AIT and fiscal multiplier.

[4]See, for example, Hazell et al. (2020) and Stock and Watson (2020)

The remainder of the paper proceeds as follows. Section 1.2 reviews the related literature. Section 1.3 introduces the model and Section 1.4 studies the AIT features in the stochastic steady states. Section 1.5 compares AITs with different window lengths and the fiscal multiplier in AITs is studied in Section 1.6. Section 1.7 checks the sensitivity under various alternative assumptions and Section 1.8 concludes.

1.2. Literature Review

My work is related to the literature on AIT. Nessén and Vestin (2005) show that AIT results in more efficient outcomes than IT, although it is dominated by price level targeting(PLT). However, when the Phillips curve has both forward and backward looking components, it is possible for AIT to outperform IT and PLT. They also report that the optimal averaging window depends on the relative weight on output stabilization in the welfare loss function. Unlike them, I compare AITs in terms of social welfare in their SSS. I show that 6-year window AIT maximizes social welfare instead of longer window AIT. As I mentioned before, my result does not require backward looking component in the Phillips curve. Budianto et al. (2020) show that, under rational expectations, the welfare maximizing averaging window is very long and it converges to PLT. When one assumes boundedly-rational expectations, the optimal averaging window is finite. Their results are based on the linear-quadratic solution method which has a certainty equivalent property. By contrast, my results are based on fully nonlinear solution method so that it captures the expectation effects responding to the future uncertainty in the model. It turns out that those effects are nontrivial. Svensson (2020) argues that AIT represents the continuity of the current IT with considerable improvements in cases of possible binding ZLB in the future and flattening Phillips curve.

While the previous authors model AIT as a loss function with average inflations as an argument, the others, such as Mertens and Williams (2019), Amano et al. (2020) and Coenen et al. (2021), model AIT as an instrument rule. Mertens and Williams (2019) show that AIT can eliminate deflation bias from the possibility of ZLB and stabilize the economy better because inflation expectations are already high when the economy is actually constrained by the ZLB. Amano et al. (2020) examine the optimal averaging window of AIT and find it to be relatively short. Coenen et al. (2021) find that AIT can largely mitigate the negative biases and stabilize the economy better if they are well understood by the private sector. While this chapter also takes the same approach, it is different from theirs in that none of them solves the model nonlinearly and studies how the adoption of AIT affects the fiscal multiplier.

This chapter also relates to the literature on the fiscal multiplier in the New-Keynesian(NK) model. Among them are Christiano et al. (2011), Woodford (2011), Eggertsson (2011) and Leeper et al. (2017). Christiano et al. (2011) show that the fiscal multiplier is larger than one when the ZLB binds with the medium-size DSGE model. Woodford (2011) explains the factors that determine the fiscal multiplier analytically using simple NK model. He shows that sticky prices or wages allow for larger multiplier than in a neoclassical model, and the binding ZLB leads to the above one multiplier. Eggertsson (2011) explores which fiscal policy is effective at the ZLB. He finds that the increase of government spending is effective because it generates excess demands in the recessions. It is also documented that policies that expand supply such as some tax cuts are not desirable. Leeper et al. (2017) report that monetary-fiscal regime is important for the size and persistence of multipliers. That is, they are larger and more persistent with active fiscal policy together with passive monetary policy. All of them study the fiscal multiplier under IT with the ZLB. Unlike them, I explore the fiscal multiplier under AIT both outside and at the ZLB.

My work also builds on the literature which compares the linear and nonlinear solution method. Among them are Boneva et al. (2016), Eggertsson and Singh (2019), Fernández-Villaverde et al. (2015), Lindé and Trabandt (2018) and Nakata (2017). Importantly, none of the above papers considers the case of AIT as a monetary policy rule when the fiscal multiplier is calculated. Boneva et al. (2016) show that the fiscal multiplier is smaller when the model is solved nonlinearly compared to when solved linearly. Lindé and Trabandt (2018) also show that the nonlinear solution is associated with a much smaller multiplier than the linearized solution at the ZLB. Unlike others, they consider a case of a Kimball (1995) aggregator to capture a flat Phillips curve and frequent price changes, which are evident from macro and micro data. On the contrary, Eggertsson and Singh (2019) report that they are not that different under first-specific labor markets assumption, which makes price dispersion irrelevant in dynamics. Fernández-Villaverde et al. (2015) and Nakata (2017) show that the possible shocks in the future affect the equilibrium dynamics of the model nontrivially, which advocates the nonlinear solution method. By contrast, I show that one needs to use the nonlinear solution method to compare various AITs with different window length to capture the different expectation effects. In addition, it is shown that the fiscal multiplier is also influenced by those effects.

1.3. Model

The model is based on a standard New Keynesian model (see, for example Bianchi et al. (2021)) with the zero lower bound and average inflation targeting rule. There are 3 sectors in the economy: household, firms and government. Households consume the final goods, save via government bonds, and supply labor to intermediate firms. The firm sector consists of final goods firms and a continuum of monopolistic intermediate goods firms. The final goods firms produce the final goods by aggregating the intermediate goods using a CES technology. Each intermediate goods firm hires labor to produce differentiated goods to be sold to final goods firms in a monopolistic competitive market. Because of its monopolistic power, the intermediate goods firms set their goods price subject to price adjustment costs in the spirit of Rotemberg (1982). In the government sector, the monetary authority sets the interest rate for the government bonds following the feedback rule, whereas the fiscal authority runs a balanced budget constraint in every period.

1.3.1. Households. There is a representative household who consumes c_t , supplies labor H_t, and saves using one period government bonds B_t in zero net supply to maximize the expected lifetime utility in every period

$$E_0 \sum_{t=0}^{\infty} \beta^t \xi_t \left[\frac{(c_t - hc_{t-1}^A)^{1-\sigma}}{1-\sigma} - \chi \frac{H_t^{1+\eta}}{1+\eta} \right] \tag{1.1}$$

subject to the budget constraint

$$P_t c_t + B_t = P_t w_t H_t + R_{t-1} B_{t-1} + T_t + P_t div_t \tag{1.2}$$

where c_t^A is aggregate consumption[5], P_t is the price level of final goods, w_t is the real wage, R_t is the gross nominal interest rate, T_t is lump-sum tax and div_t is real profits from the firm sectors. The parameter h captures the degree of consumption habits. ξ_t is the preference shock and follows AR(1) process in logs $ln(\xi_t) = \rho_\xi ln(\xi_{t-1}) + \sigma^\xi \epsilon_t^\xi$, where $\epsilon_t^\xi \sim N(0,1)$. σ^ξ is the standard deviation of the preference shocks.

1.3.2. Firms. Final goods firms buy the intermediate goods from intermediate goods firms and produce the final goods using a CES technology:

$$y_t = \left(\int_0^1 y_t(j)^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}} \tag{1.3}$$

where $y_t(j)$ is the amount of the good from firm j and y_t is the amount of the final goods produced. Since the final goods firm is in the competitive market, from the profit maximization problem, the demand for the differentiated good j is derived as

$$y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\epsilon} y_t \tag{1.4}$$

[5]Unlike the individual consumption level, the habit based on aggregate consumption does not complicate the Lagrangian multiplier of the household budget constraint. See A.7 in Appendix A.3.

where $P_t(j)$ is the price of firm j's goods and P_t is the price of the final goods. Price for the final goods is expressed as

$$P_t = \left[\int_0^1 P_t(j)^{1-\epsilon} dj \right]^{\frac{1}{1-\epsilon}} \tag{1.5}$$

Given the demand for the intermediated good j, the firm j produces output with labor, $y_t(j) = H_t(j)$. Because of its monopolistic power, the firm j sets its own price $P_t(j)$ so as to maximize expected lifetime profits subject to the price adjustment costs in units of the final goods:

$$\begin{aligned} \max_{P_t(j)} E_t \sum_{s=0}^{\infty} \beta^{t+s} \frac{\lambda_{t+s}}{\lambda_t} \frac{\xi_{t+s}}{\xi_t} \Bigg[\frac{P_t(j)}{P_{t+s}} \left(\frac{P_t(j)}{P_{t+s}} \right)^{-\epsilon} y_{t+s} - mc_{t+s} \left(\frac{P_t(j)}{P_{t+s}} \right)^{-\epsilon} y_{t+s} \\ - \frac{\varphi}{2} \left(\frac{P_t(j)}{\Pi P_{t-1}(j)} - 1 \right)^2 y_{t+s} \Bigg] \end{aligned} \tag{1.6}$$

1.3.3. Government. The monetary authority sets the nominal interest rate R_t responding to the deviations of average inflation rate and output from their own targets. The average inflation rate, $\hat{\Pi}_t$, is defined as an exponential moving average inflation rate:

$$\hat{\Pi}_t = \alpha \Pi_t + (1 - \alpha) \hat{\Pi}_{t-1} \tag{1.7}$$

where Π_t is the one period inflation rate. This specification reduces the endogenous state variables related to the average inflation rate to the unity regardless of the averaging window.[6] The parameter α is determined in a way that given the averaging window, for example 4 years(16 quarters), the sum of weights accrued to recent 16 periods inflation rates is equal to 99.9%.[7] When $\alpha = 1$, the monetary policy is the standard inflating targeting which does not

[6] Budianto et al. (2020) also used this definition to solve the linearized model using global methods.

[7] In this example, α is determined about at the level of 0.35.

care about past inflation losses or gains. If $\alpha = 0$, the aim of the central bank is to stabilize the price level[8]. The monetary policy is constrained by a ZLB[9].

The monetary policy rule is implemented as follows

$$R_t = \max(1, R_t^n) \tag{1.8}$$

where R_t^n denote the notional rate that would be set without the ZLB constraint.

$$R_t^n = (R_{t-1}^n)^{\rho_R} \left[R \left(\frac{\hat{\Pi}_t}{\Pi} \right)^{\phi_\pi} \left(\frac{\hat{y}_t}{y_t^n} \right)^{\phi_y} \right]^{1-\rho_R} exp(\sigma^m \epsilon_t^m) \tag{1.9}$$

where R is the nominal interest rate in the steady state. Π is the monetary authority's inflation target and y_t^n is the level of output in the flexible-price economy. The inertial term is included and the parameter ρ_R is associated with the persistence of the monetary policy. ϵ_t^m is a i.i.d monetary policy shock, where $\epsilon_t^m \sim N(0,1)$. σ^m is the standard deviation of the shocks. The fiscal authority just runs balanced budget constraints in every period, which results in the resource constraint

$$c_t = y_t \left[1 - \frac{\varphi}{2} \left(\frac{\Pi_t}{\Pi} - 1 \right)^2 \right] \tag{1.10}$$

1.3.4. Model Equilibrium. An aggregate production function of the model is $y_t = H_t$. The equilibrium of the model is the sequence of $\{\lambda_t, c_t, \xi_t, R_t, \Pi_t, w_t, H_t, mc_t, y_t, R_t^n, \hat{\Pi}_t, W_t\}_{t=0}^{\infty}$ which satisfies the all first-order conditions derived from the agents' maximization problems and the monetary policy related equations along with the aggregate production function given the states of the economy.

[8]See Budianto et al. (2020) for this.

[9]The difference between the average inflation rate defined based on EMA and the rate based on SMA is the weight assigned to the past inflation rates. While SMA put the same weight on the past inflation rates, EMA assign the largest weight to the most recent inflation rate and the second largest weight to the second recent rate and so on. Hence, the average inflation rate and the recent inflation rates are more correlated in EMA rather than in SMA. Svensson (2020) paraphrases FOMC (2022) as follows: "...the FOMC would seek to mitigate deviations of [both] average [and annual] inflation from its longer-run goal and ...". This interpretation could be seen as the one possible ground of EMA over SMA.

1.3.5. Model solution and Calibration. Following Richter et al. (2014), I solve the model globally with time iteration and linear interpolation. Expectations are evaluated with Rouwenhorst (1995), which Kopecky and Suen (2010) show that it outperforms other methods for approximating autoregressive processes. A detailed description of the solution method is provided in A.3.

I set $\beta = 0.994$ to match a real interest rate at the steady state of roughly 2.5 percent on an annual basis, $\eta = 1$ to deliver a Frisch elasticity of 1, and $\chi = 1.73$, a normalization of the hours worked. The relative risk aversion parameter σ is set to 1, the Rotemberg parameter φ is set to 667 so that the slope of the New Keynesian Phillips curve is 0.01. The elasticity of substitution among good varieties to $\epsilon = 7.67$, which implies a steady-state markup of 15 percent. The habit parameter h is set to 0.5. I set the inflation target to 2%.

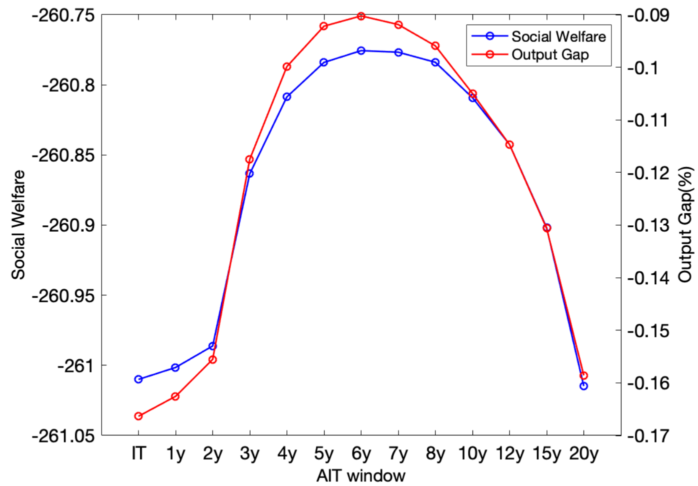
Whereas the persistence of the monetary policy rule ρ_R is set to 0.8, there are no clear guidelines about how to set ϕ_π and ϕ_y under AIT because of rare experiences of implementing AIT in the real world. Following the literature, see for example Coenen et al. (2021), ϕ_π is set to equal to the length of averaging window in annual basis.[10] This specification keeps the volatilities of the policy rates comparable across all averaging windows. For the baseline case, I set $\phi_y = 0$, and explore the effects of different values later. For the exogenous shock processes, I follow Bianchi et al. (2021) and set $\rho_\xi = 0.7$, $100\sigma_\xi = 2.16$ and $100\sigma_m = 0.42$.

1.4. Social Welfare under AIT

In this section, I compare social welfare across various averaging window AITs in the stochastic steady states(SSS). The SSS is defined as the point where the economy eventually converges in absence of shocks for a substantially long periods even though the agents perceive the uncertainty arising from the possible future shocks. Unlike SSS, the deterministic steady state(DSS) is the state where the economy would remain in absence of shocks for a

[10] In case of inflation targeting, we set ϕ_π=2. Also for 1year and 2 year AITs, ϕ_π is set to 2.

FIGURE 1.1. Social Welfare/Output Gap in Stochastic Steady State



Note: The blue line(left axis) shows the social welfare in AIT with various averaging windows in each SSS. The red line(right axis) shows corresponding output gaps relative to flexible price economy.

substantially long periods once the future uncertainty is ignored. Naturally, the difference between the two states has been deemed to capture the expectation effects.

1.4.1. Social welfare in stochastic steady state. The figure 1.1 shows social welfare(blue line, left axis) in Equation (1.1) and output gap(red line, right axis) as a function of averaging windows of AIT. The social welfare increases as the window is lengthened up to 6 years, but starts declining beyond that point. As is well known, the presence of ZLB constraint causes the welfare losses under IT because the possibility of ZLB in the future hampers well anchored inflation expectations. In the economy with AIT, private sector expects lower-for-longer policy in the ZLB, thus higher inflation and output gap in the future. Since the heightened inflation expectation lowers the likelihood of ZLB in the future, welfare losses arising from ZLB are alleviated to some degrees. The window length determines how strong these effects are.

The blue line shows that up to 6 years, the expectation effects are favorable enough to reduce the welfare losses so that social welfare goes up. As the window length becomes longer than 6 years, the optimistic expectations are so strong that output and inflation tend to grow beyond the desired targets. To meet inflation target, the central bank needs to raise the policy rate. While this policy action drags down the inflation close to the target, the output falls below target because of well anchored inflation expectations, thus higher real interest rates. That is, too strong stimulative expectation effects from longer averaging windows hamper social welfare in the long run through the lowered output. This is demonstrated by the red line. As the inflation is anchored around the target, what determines the social welfare in SSS is the output gap.

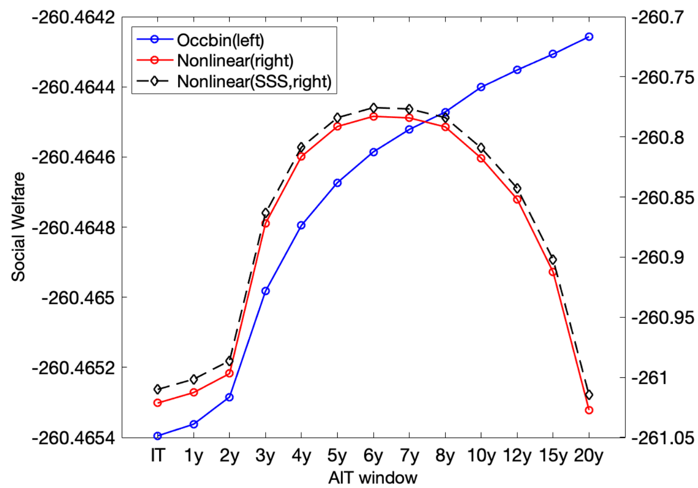
1.4.2. The importance of solution method. To see how much the solution method is important to capture the nonlinear relationship between the social welfare and the AIT window, I compare the social welfare from the global method with the result from the linear approximation. For the latter, because of the occasional binding ZLB constraint, I solve the model using the method developed in Guerrieri and Iacoviello (2015) which uses a first-order perturbation approach in a piecewise linear fashion. One problem of this method is that, by nature of first-order approximation, a certainty equivalence property holds, which means that the stochastic steady state is identical to the deterministic steady state. Hence, the social welfares in SSS from different AIT windows are the same.

To circumvent this issue, I first simulate the model solved by linear method and that by nonlinear method for a long period with a series of arbitrary shocks, then average the resulting social welfares over the period[11]. While this simulation does not generate the exactly the same level of the SSS welfares documented in the previous subsection for the nonlinear method, it mimics them quite well.

Figure 1.2 displays the results of the simulations. The red line represents the social welfares from nonlinear solution method, while the blue line shows the social welfares from

[11] I simulate the model 100,000 times and get rid of the first 10,000 results to calculate the average of social welfare. The same series of shocks is used to simulate the model for each solution method with different AIT window.

FIGURE 1.2. Linear vs Nonlinear solution method



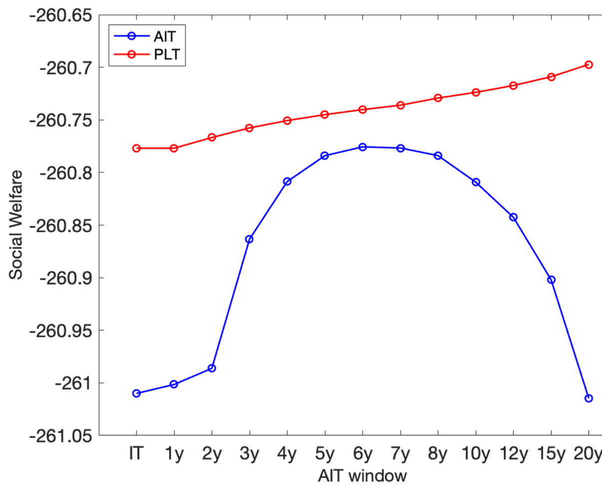
Note: While blue line(Occbin) represents the results from the method of a first-order perturbation approach, red line(Nonlinear) represents the results from the global method. The social welfares are calculate based on simulations. Black dashed line(Nonlinear, SSS) shows the SSS social welfares.

the linear solution method. The black dashed line represents the social welfares in the SSS. As I mentioned, the red line and the black dashed line are very close each other, which implies that social welfares based on simulations are not such a bad proxy for the values in SSS.

The blue line demonstrates that when we solve the model linearly, the social welfare increases as the AIT window gets longer. However, if the model solved nonlinearly, the social welfare decreases once the window goes beyond 6 year. Again, this is because a first-order approximation fails to capture the mechanism through which the agents respond to the uncertainty in the model. Therefore, the linear solution does not capture the different possibility of binding constraint in the future depending to the window length. What this means is that it is important to solve the model nonlinearly if we want to compare the AITs with differnt windows.

1.4.3. AIT vs PLT. Next, I compare AIT with PLT in terms of welfare. Since PLT mimics the optimal monetary policy well, I take PLT as the optimal policy here and see how

FIGURE 1.3. Social Welfare of AIT vs PLT



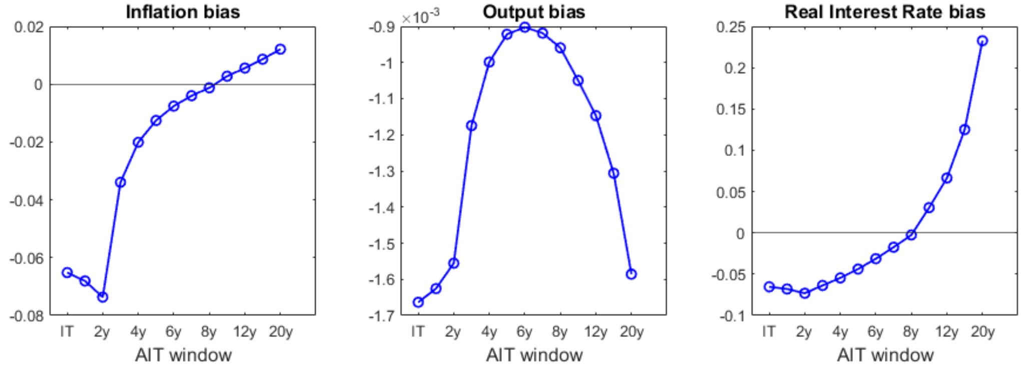
Note: The blue line shows the social welfare in AIT with various averaging windows in each SSS. The red line shows the social welfare in PLT with the same coefficients of inflation responses in the policy rule of the corresponding AIT.

closely AITs follow the performance of PLT[12]. Figure 1.3 shows the results and a couple of comments follow[13]. Unlike AIT, high coefficients of inflation responses(ϕ_π) in PLT imply welfare improvement. Actually, this is also true for AIT. Given a specific window length, the higher the coefficients are, the larger the social welfare is. This is because stabilizing fluctuations caused by demand shocks does not result in trade-off between stabilizing inflation and output gap.

The welfare under PLT is always higher than the welfare under AIT with any window lengths. Still, the performance under 6-year window AIT is quite close to the corresponding PLT outcomes. To put this difference into interpretable units, I translate the welfare losses to consumption equivalent units[14]. 6-year window AIT results in a welfare decline equivalent to permanently reducing consumption by 0.02 percent in the PLT economy. Interestingly,

[12]I take this approach because deriving optimal policy in a nonlinear fashion is not simple. I leave this for future research.
[13]Note that to compare 4-year window AIT with PLT, I set the coefficients of inflation responses in the policy rule to the same number in AIT. This applies to all window lengths.
[14]Appendix A.2 explains how I change the welfare into consumption equivalent units.

FIGURE 1.4. Macroeconomic biases



Note: The inflation bias(left plot), the output bias(middle plot), and the real interest rate bias(right plot) are computed by taking the difference between those values at the SSS and their value at DSS.The inflation and the real interest rate biases are expressed in annualized percentage points and the output gap in percentage points.

the social welfare(-260.77) under 6-year window AIT is comparable to that(-260.77) under PLT with $\phi_\pi = 2$.

1.4.4. Macroeconomic biases. Finally, Figure 1.4 shows how the macroeconomic biases due to the ZLB vary as a function of AIT window length. I examine the biases of inflation, output and real interest rate in SSS, which are computed by taking the difference between those values at the SSS and their value at DSS. We observe that medium averaging window AITs are effective to mitigate all macroeconomic distortions. Particularly, 8-year window AIT almost closes three gaps. One thing to note is that inflation bias and output bias move in the opposite direction in the longer window AITs. In those regimes, downside risk due to ZLB binding is low. However, once that happens, private sector expects long periods of future inflation and output deviations in the positive direction. This expectation effect is so strong that it outweighs the downside risks. The point where two opposite effects are balanced is where the central bank raises the policy rate to mitigate the expectation effects, which results in high real interest rates and low output gap.

1.5. Macroeconomic Dynamics under AIT

In this section, I study the macroeconomic dynamic properties under various window length of AITs. Comparing AITs with different averaging windows are tricky because the information in the past average inflation rates, $\hat{\Pi}_{t-1}$, is not the same across different regimes. For instance, when the average inflation target is 2%, 1.2% of past average inflation under 4-year window AIT means much larger or longer past inflation losses relative to the value of 1.2% under 2-year window AIT.

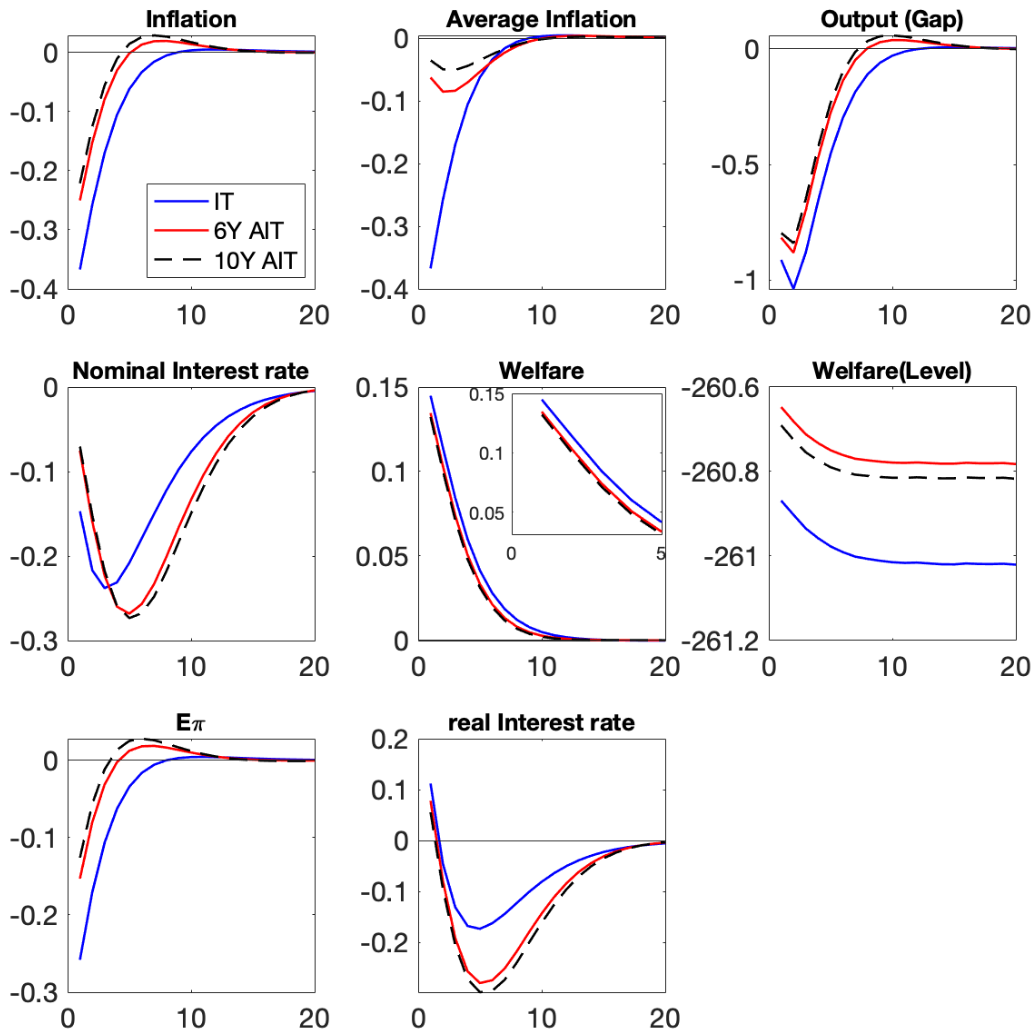
To circumvent this issue, I assume that the economies under the different windows of AIT stay initially at their own SSS whenever I compare dynamics. This means that any initial differences among various regimes arise not because of different information in $\hat{\Pi}_{t-1}$. After that, I investigate the main source of social welfare improvement when AIT is adopted between the two: one is the response to the average inflation rate instead of the period inflation rate, and the other is the higher coefficient of inflation gap in the policy rule.

Given the same size of the shocks across all regimes, the economy under longer window AIT stabilize the dynamics from the shocks better. Based on this, one may expect that the marginal welfare gains would be higher in longer window AIT economy. According to my simulations, that is not the case.

Figure 1.5 displays the generalized impulse response functions(GIRF)[15] to negative one standard preference shocks in 3 different monetary policy rule: IT(blue line), 6-year AIT(red line) and 10-year AIT(black dashed line). As the negative shocks hit the economy, inflation falls, but less under AITs. This is because of well-known expectation channel. Since AITs promise future inflation and positive output gap to mitigate today's recession, inflation expectations rise. This can be seen from the left panel in the bottom row. Whereas the inflation expectation falls by 0.24% under IT on impact, they drop by 0.14% and 0.11%

[15]Since certainty equivalence does not hold in non-linearly solved model, GIRF is more suitable way to discuss the resutls. See Appendix C.2 for detailed explanation.

FIGURE 1.5. GIRF to Preference shocks



Note: This figure shows GIRF to negative one standard preference shocks in 3 economies with different monetary policy rule. X-axis means horizon. Output is expressed in terms of percentage point, and welfare is the difference between two figures. The remaining variables are expressed in terms of annualized percentage points.

under 6-year and 10-year AITs, respectively. Unlike IT, we observe overshoot of inflation expectation for a time being.

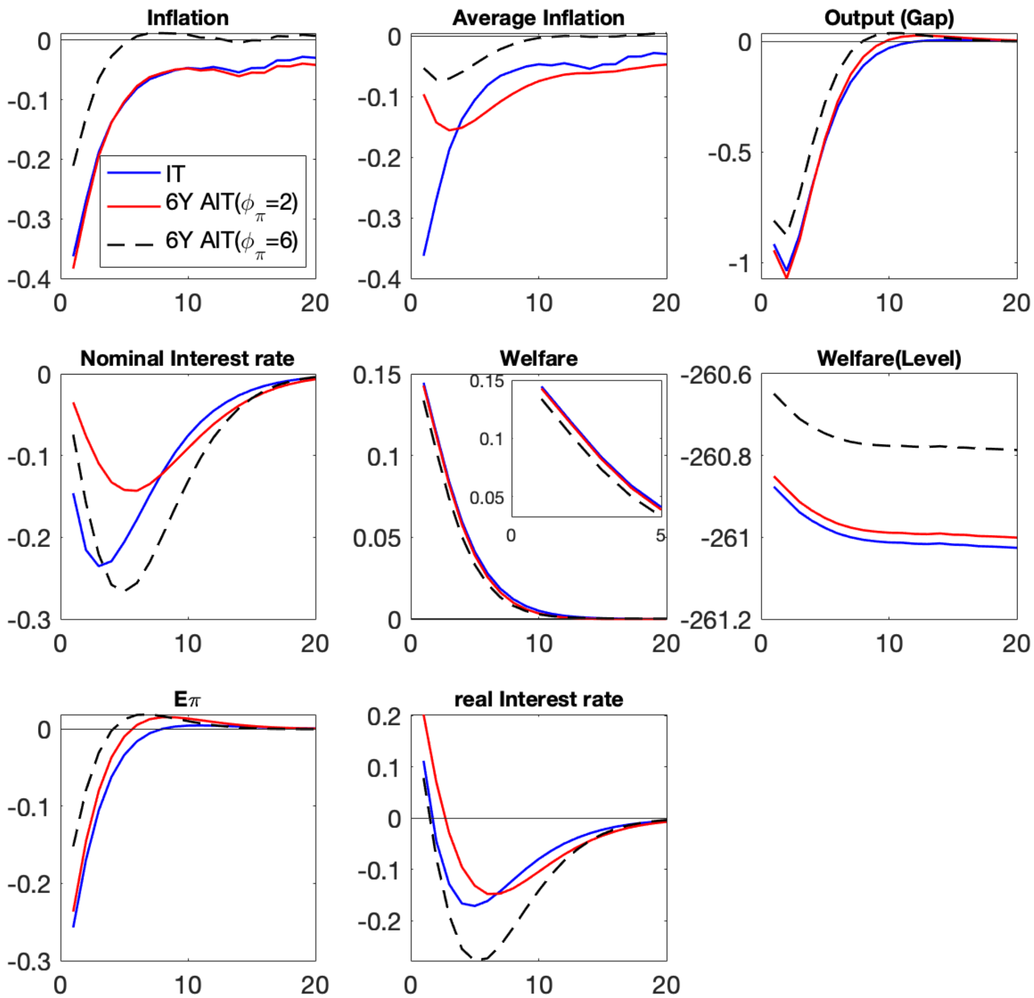
The small drop in inflation and long windows for calculating average inflation result in less changes in average inflation rate under AITs, too. This leads to larger decrease in nominal interest rate under IT on impact relative to AIT regimes. However, the central banks implementing AITs lower the nominal interest rates more to generate inflation expectation afterward. The left panel in the second row demonstrates this dynamics. Due to low real interest rate under AITs resulted from high inflation expectations, output also falls less on impact onward under AITs.

All the above story is well-known AIT dynamics. Here, I additionally report the dynamics of social welfare. The middle panel in the second row shows the welfare dynamics. One thing to note is that the panel does not compare the level of social welfare in three economies. Instead, it captures marginal changes of social welfare responding to the shocks. The panel illustrates that the marginal gains from each monetary policy are comparable one another. That is, the window length of AIT has little effects on the marginal changes of social welfare. This is somewhat surprising given that 10-year AIT stabilizes the economy more successfully in terms of average inflation and output (gap).

The right panel in the second row shows the level of social welfare after shocks hit the economy. Since the each economy starts from its own SSS, 6-year AIT economy begins at the highest level, followed by 10-year AIT and IT. Due to the similar marginal effects across regimes, the order of social welfare does not change throughout the horizon. That is, the level effects dominate the marginal effects.

In the model, the adoption of AIT brings about two changes in the monetary policy rule. The central bank responds to the average inflation gap instead of the period inflation gap. In addition, it can responds to the gap more aggressively that in IT. In this subsection, I investigate the effects arising from each component. I refer to the effects due to the former as the targeting effect, whereas those due to the latter as the coefficient effect.

FIGURE 1.6. GIRF to Preference shocks with different ϕ_π



Note: This figure shows GIRF to negative one standard preference shocks in 3 economies with different monetary policy rule. X-axis means horizon. Output is expressed in terms of percentage point, and welfare is the difference between two figures. The remaining variables are expressed in terms of annualized percentage points.

Figure 1.6 displays the result. The blue line corresponds to the case of IT, which serves as the benchmark. The red line represents 6-year window AIT with $\phi_\pi = 2$, and the black dashed line is the case of 6-year window AIT with $\phi_\pi = 6$. Therefore, the gap between the blue line and red line is interpreted as the targeting effects, while the difference between the red line and black dashed line is read as the coefficient effect.

Let's first take a look at the targeting effect. The targeting effect is captured in the dynamics of nominal interest rate. Because of different targeting objects, the nominal rates in red line declines less compared to the IT case. One thing to note is that, with the same ϕ_π, AIT does not show lower-for-longer policy any more, which leads to small improvement of inflation expectations. The real interest rates increase further under AIT compared to IT due to the less responses of the nominal interest rates. Therefore, the output falls slightly more than the blue line in the short run.

When the central bank responds more aggressively to the average inflation gap, the lower-for-longer policy is implemented and the inflation expectation rises a lot compared to the red line. Both of these two result in lower real interest rates, thus smaller decrease of output. This experiment shows that what boosts the inflation expectation is not the targeting effects, but the coefficients effects. Therefore, when the monetary authority switches to AIT from IT, it seems important to decide carefully how aggressively respond to the average inflation gap in addition to the window length.

1.6. The size of the fiscal multiplier

In this section, I study the effects of AIT on the government spending multiplier. As the adoption of AIT changes the behavior of nominal interest rates and inflation expectations as well as output, it also affects the multiplier both at the ZLB and outside the ZLB. To analyze this effect, I introduce government spending shocks which follows AR(1) processes instead of monetary policy shocks:

$$ln\frac{g_t}{g} = \rho_g ln\frac{g_{t-1}}{g} + \sigma^g \epsilon_t^g \tag{1.11}$$

where g is the steady-state government spending and $\epsilon_t^g \sim N(0,1)$. I set $\rho_g = 0.81$ and $100\sigma^g = 0.96$ for the baseline parameterization. To facilitate simple computation and easy comparison to the literature, I assume no habit in the utility function and no inertia in the monetary policy rule. Following Eggertsson and Singh (2019), I further assume that the price adjustment costs are not physical menu costs, but are only perceived by firms when they maximize their profit[16]. Therefore, the price adjustment costs are not appeared in the resource constraint.

Throughout the section, I report the cumulative fiscal multiplier for output computed as

$$M(k) = \frac{\sum_{s=1}^{k} \frac{\Delta y_{t+s-1}}{\Pi_{j=1}^{s} r_{t+j-1}}}{\sum_{s=1}^{k} \frac{\Delta g_{t+s-1}}{\Pi_{j=1}^{s} r_{t+j-1}}} \tag{1.12}$$

where Δ denotes the level changes between simulated paths with and without a government spending increase, and $r_t = E_t\left[\frac{R_t}{\Pi_{t+1}}\right]$ is the real interest rate.

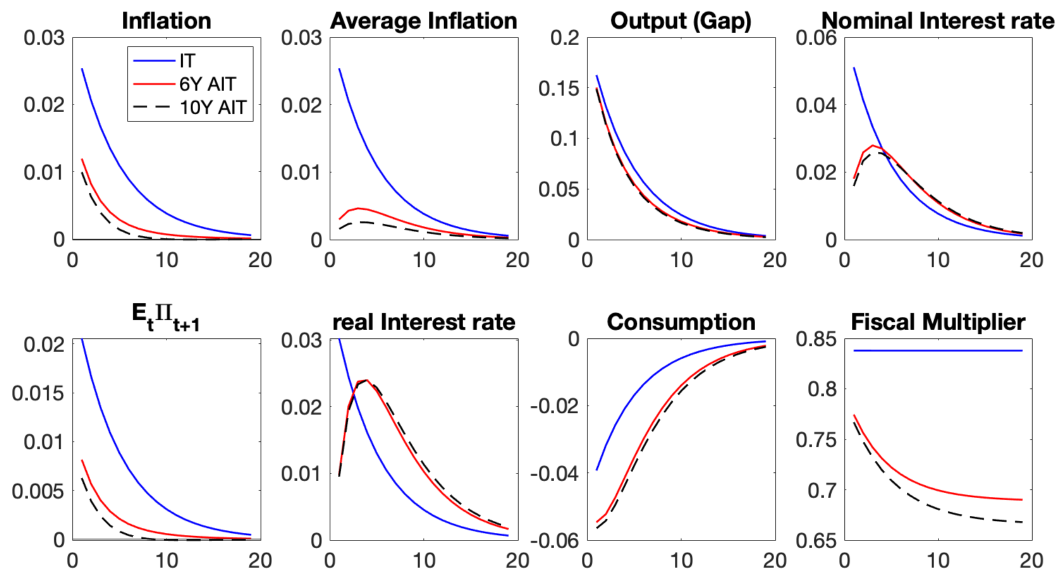
Since the model is solved nonlinearly, the multiplier depends on the initial state of the economy. I first quantify the multiplier outside the ZLB and turn to the ZLB case.

1.6.1. Multiplier outside the ZLB. In this subsection, I report the multiplier outside the ZLB. To see how the different window length affects the fiscal multiplier, I compare 6-year and 10-year window AITs to IT. Each economy with different monetary policy rule starts at its own SSS and the government spending increases by 1% following the process of (1.11). I plot the result in Figure A.7. The most right panel in the second row shows the fiscal multipliers. I highlight two points.

First, the multipliers under AIT are smaller than IT case. An increased demand due to higher government spending results in the rise of inflation and output. Because of well-known crowding-out effects the multiplier stays below the unity under IT. In case of AIT, private agents expect higher for longer policy from the central bank given the inflation gains from the government spending increase. This drags down the inflation expectation, thus inflation compared to IT. Therefore, the nominal interest jumps up less at impact responding to

[16]Or, I can assume the the costs are rebased to the household. The result is the same.

FIGURE 1.7. GIRF to Govermnet spending shocks and Fiscal Multiplier outside the ZLB



Note: Except for output, consumption and fiscal multiplier, the y-axis is the annualized percentage point difference between a path with and without government spending shocks. Output is the difference between two paths scaled by the SSS values. Fiscal multiplier is the cumulative multiplier computed by equation (3.28).

the smaller increase of average inflation rates, but higher for longer policy is implemented thereafter.

The real interest rate mimics the movement of the nominal interest rates. Even though the real rate under AIT is lower than IT at impact, it increases more after a few periods. That's why the output under AIT increases less than IT case throughout the horizon. The smaller change in output combined with larger jump in real interest rates lead to the multiplier below IT case. That is, the crowding-out effects become more potent in case of AIT. This is shown in the third panel of the second row, which displays the consumption responses.

Second, the multiplier declines as the window length increases. Since the expectation effects under longer window AIT are stronger, the real interest rates rise more than the shorter AIT case. This leads the consumption to fall further, which results in the smaller multiplier in 10-year AIT case.

One thing to note is that the fiscal multiplier outside the ZLB seems not as low as reported in the literature. For example, Fernández-Villaverde et al. (2015) reported 0.54 as a fiscal multiplier at impact outside the ZLB when the model is solved non-linearly. This arises from the fact that the monetary policy rule in my model does not respond to the output gap. If I allowed the central bank to aim to stabilize the output gap also, the multiplier would be much lower[17]. Still, the points I explained above are robust to that.

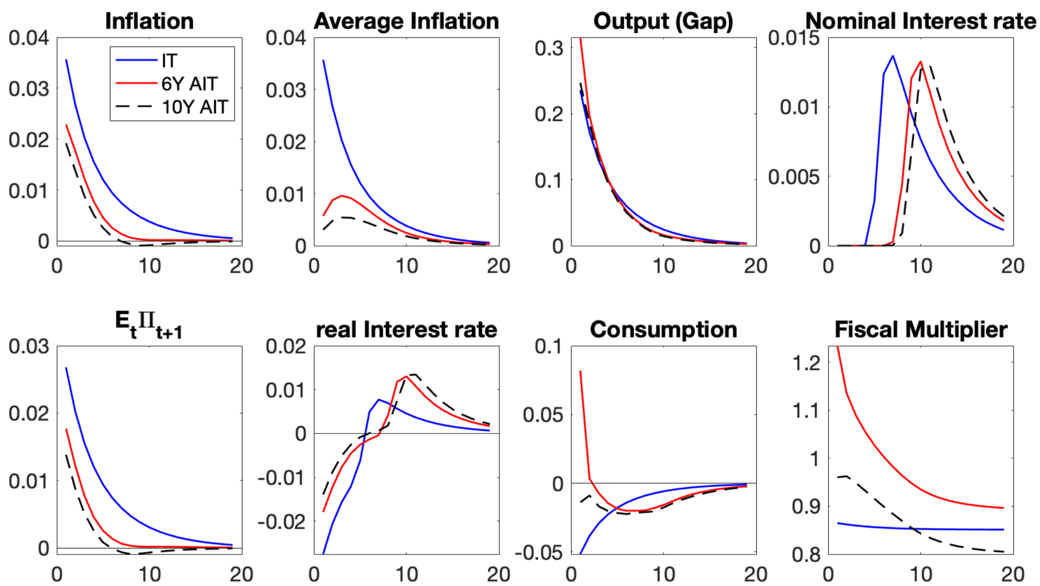
1.6.2. Multiplier at the ZLB. Next, I investigate the government spending multiplier at the ZLB. Each economy starts at its own SSS in period 0. I inject a series of negative preference shocks in period 1 and 2 in each economy, which sends the economy under IT to the ZLB, on average, for 5 consecutive quarters. Given the same series of shocks, the economies under AITs experience longer ZLB episode because of their lower-for-longer policy feature. The government spending rises by about 1% in period 2 when the shock ends but the economy still remains at ZLB. Figure A.8 shows the result and a couple of things are worth highlighting.

First, the multipliers under IT seldom change compared to the outside ZLB case. One reason for that is the flat Phillips curve. The main channel at ZLB for government spending to stimulate the economy is through the rise in expected inflation. The flat Phillips curve attenuates this channel so that the decrease of real interest rate is limited[18]. In that sense, the flat Phillips curve weakens the substitution effects from the increase of government spending.

Another ground is the dominance of wealth effect over substitution effect, which is implied by the decrease of consumption at impact despite the fact that the real interest rates fall. Since the government spending increases even after the economy exit the ZLB because of its

[17]In the next section, I show the result with $\phi_y = 0.1$.
[18]This point is also documented by Horvath et al. (2020).

FIGURE 1.8. GIRF to Govermnet spending shocks and Fiscal Multiplier at the ZLB



Note: Except for output, consumption and fiscal multiplier, the y-axis is the annualized percentage point difference between a path with and without government spending shocks. Output is the difference between two paths scaled by the SSS values. Fiscal multiplier is the cumulative multiplier computed by equation (3.28).

persistence, the negative wealth effect dominates the attenuated substitution effect arising from lower real interest rates.

Second, unlike the IT case, the multipliers under AITs increase for both windows. Numerically speaking, the multipliers at impact are about 1.23 and 0.96 for 6-year and 10-year AIT, respectively, that lie below 0.8 outside the ZLB for both. Since the agents expect longer ZLB episode under AIT, inflation expectation rises more so that the weakened substitution effect is restored to some degrees.

It turns out that the restored substitution effect is strong enough to dominate wealth effect under 6-year AIT, so that the consumption increases and the fiscal multiplier lies above one at impact. On the contrary, in 10-year AIT, the inflation expectation rise less compared to 6-year AIT, so that the restored substitution effect fails to overturn the dominance of wealth effect. Therefore, the on impact multiplier does not exceed one, even though it is much higher than that outside the ZLB.

To sum up, as the recession becomes severe, the fiscal policy under AIT is more effective compared to the IT case. This results is based on the assumption that the slope of Phillips curve is very flat and the government spending is persistent, which are broadly supported by the empirical evidence.

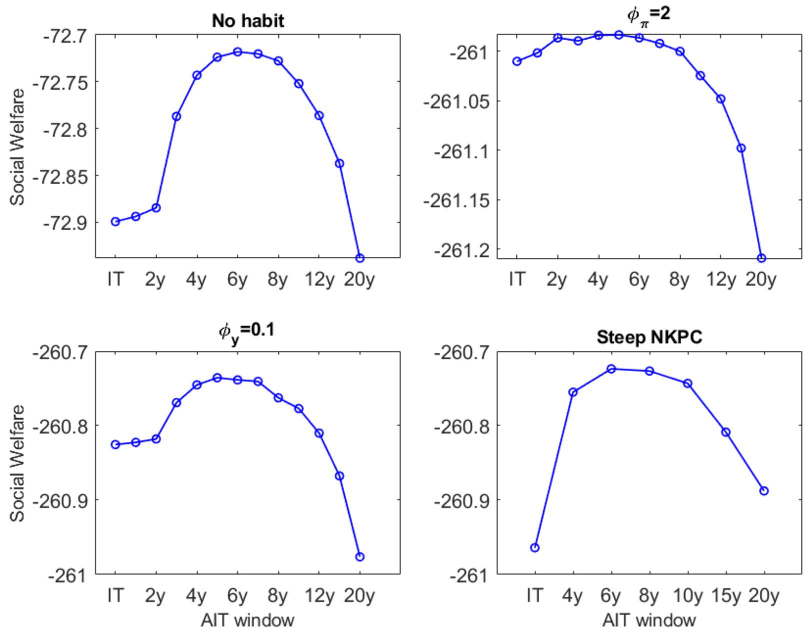
1.7. Sensitivity analysis

In this section, I conduct several sensitivity analysis for social welfare in SSS and fiscal multiplier, respectively.

1.7.1. Social welfare in SSS. In section 1.4, I show that the social welfare increases non-monotonically with the AIT window length. In this subsection, I check how robust this result is depending on the different assumptions: no habit, the same value of $\phi_\pi(= 2)$, response of monetary policy rule to output gap and steep Phillips curve.

Figure 1.9 shows the results. The first left panel in the first row corresponds to the case of no habit. The presence of habit does not affect the nonlinear property of social welfare, though it changes the level of social welfare significantly for all window lengths. One might guess that the nonlinear property would arise from the different responses to inflation gap in the monetary policy rule. It turns out that it is not the case, though. The right panel of the first row shows the result when the response to inflation gap in the monetary policy rule remains unchanged at $\phi_\pi = 2$ across AIT windows. While the welfare gains from the short to the medium windows are not significant, the losses from the medium to the long windows seems still nontrivial. Next, I investigate the case of $\phi_y = 0.1$ and steep Phillips curve. The second row of the figure corresponds to these. None of them changes the nonlinear properties.

Figure 1.9. Social welfare in SSS in various environments



Note: No habit means $h = 0$ in the model. $\phi_\pi = 2$ is the case when the response to inflation gap in the monetary policy rule remains unchanged across AIT windows. $\phi_y = 0.1$ is the case when the central bank responds to the output gap in addition to inflation gap with baseline parameterization of ϕ_π. Steep NKPC corresponds to the case of smaller φ.

1.7.2. Fiscal multiplier. In section 1.6, I show how fiscal multiplier changes with the AIT window length both outside the ZLB and at the ZLB. In this subsection, I check how robust these results are depending on the different assumptions: steep NKPC, response of monetary policy rule to output gap and less persistent government spending shocks. The figure 1.10 displays the results. The first column shows the multipliers outside the ZLB and the second one is for at the ZLB[19].

Steep Phillips curve. The first row shows the multipliers when the slope of linearized Phillips curve is 0.03 instead of baseline case of 0.01. As mentioned before, the flat Phillips curve results in the attenuation of substitution effects. With the steep NKPC, on the contrary, the substitution effects become resorted so that, at the ZLB, the fiscal multiplier of IT rises above two at impact, which is larger than that of 6-year AIT or 10-year AIT.

[19]GIRFs to each case is presented in Appendix A.6

Outside the ZLB, the multipliers are lower than the baseline case. This is because the inflation rises more with the steep NKPC responding to the increase of government spending. The central bank raises the nominal interest rates more than the increase of inflation, which raises the real interest rates further. Therefore, the output increase less than the baseline case for all 3 policy rules.

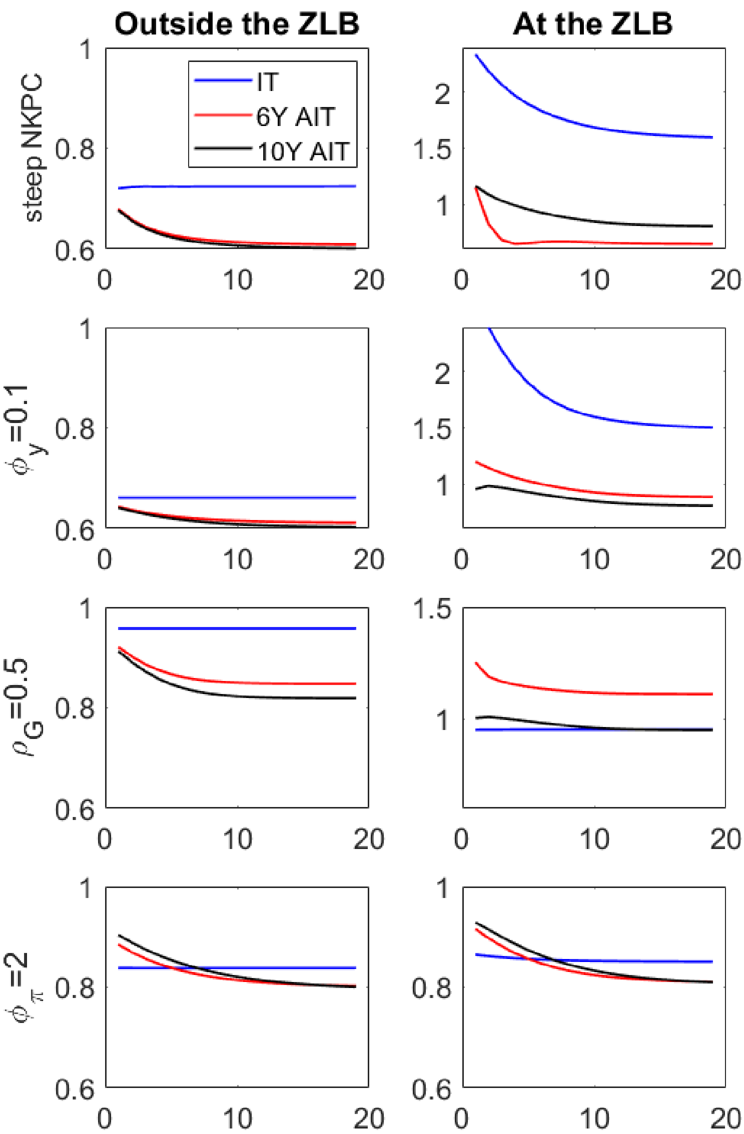
Response to output gap in monetary policy rule. The second row corresponds to the inclusion of the response of output gap in the monetary policy rule. I assume $\phi_y = 0.1$, which is the value widely used in the literature[20]. Outside the ZLB, the multipliers are again lower than the baseline case because the central bank raises the nominal interest rates further responding to the inflation gain as well as output gain. This reinforces the crowding-out effects so that multipliers fall.

At the ZLB, the inclusion of ϕ_y lengthens the ZLB episodes. Therefore, the increase of government spending raises the inflation expectation and lowers the real interest rates further relative to the baseline case. This effect is big enough for IT case to overturn the dominance of wealth effect so that the at impact multiplier exceeds two. Unlike the IT case, the inflation expectation rarely changes compared to the baseline case under AITs despite the inclusion of ϕ_y. This is reflected in the similar dynamics of multipliers in both cases. This is because the response to output gap does not lengthen the expected ZLB duration under AIT meaningfully whose duration is already expanded by the adoption of AIT itself.

Less persistent Government spending shocks. The third row displays the multiplier with the less persistent government spending processes. That is, I assume $\rho_G = 0.5$ instead of 0.81. The less persistent processes imply the smaller wealth effect regardless of the binding ZLB. As can be seen in the left panel, the multipliers outside the ZLB is very high and it is close to the unity for IT case because of smaller wealth effect. While the multipliers under AIT are also increased, they are still lower than IT.

[20]Fernández-Villaverde et al. (2015) used $\phi_y = 0.25$, which is higher than what is used here. If I use the same value, the fiscal multiplier would fall further.

Figure 1.10. Fiscal Multipliers in various environments



Note: Fiscal multiplier is the cumulative multiplier computed by equation (3.28). The first row shows the multipliers when the slope of linearized Phillips curve is 0.03 instead of baseline case of 0.01. The second row corresponds to the monetary policy rule responding to the output gap as well as inflation gap. While the third row displays the case of less persistent government spending shocks, the last row shows the case of $\phi_\pi = 2$ for AITs. The blue line, red line and black line represent IT, 6-year AIT, and 10-year AIT, respectively. The y-axis represents the size of fiscal multiplier for all panels.

At the ZLB, also, the multiplier increases relative to the baseline case. Nevertheless, the multipliers are not that much different from the baseline case, which implies that the attenuated substitution effect by the flat Phillips curve is strong.

Smaller response to inflation gap in monetary policy rule. The last row shows the case of $\phi_\pi = 2$ for AITs in the monetary policy rule. The smaller response to inflation gap arising from the increase of government spending results in the less rise of the policy rate and the more increase in inflation expectation. This leads to the much lower real interest rate, which mitigate the crowding-out effects. As a result, unlike the baseline case, the fiscal multipliers under AIT at impact are higher than in the AIT.

At the ZLB, the multipliers are not that different from those outside the ZLB, as shown in the baseline IT case. The smaller response to the inflation gap mitigates the lower-for-longer policy so that the ZLB duration under IT and AIT are similar. Therefore, the real interest rates fall less than the baseline case so that the substitution effects are weakned. Given the flat Phillips curve and the persistent government spending, the wealth effect dominates and the consumptions under AIT also fall as in the IT case.

1.8. Conclusion

In this chapter, I show that the averaging window can affect the equilibrium dynamics because the agents form their expectations differently depending on the window length. The social welfare increase up to medium window length, but once it goes beyond certain threshold, the longer window AIT lowers the social welfare. This results arises only when the model is solved nonlinearly. Therefore, it seems important to more rely on the global method to analyze the effects of AIT in various terms.

I also study the effects of AIT on the fiscal multiplier both outside the ZLB and at the ZLB. Outside the ZLB, the fiscal multiplier under AIT is lower than in IT case because of lower inflation expectation and higher-for-longer policy. This reinforces the crowding-out effect under AIT. Those effects are stronger as the averaging window gets longer. At the ZLB, I find that the increase of government spending is more effective under AIT compared to IT. Given the flat Phillips curve and persistent government spending processes, the multiplier under IT rarely changes relative to the outside ZLB case. Unlike IT case, the lower-for-longer policy reinforces the private sector's inflation expectations so that the fiscal multiplier rises above one for some window length.

While I study the several new aspects of AIT in this chapter, more topics are left in front of us to understand AIT better. First, we need to study the optimal monetary policy relying on nonlinear solution method. As is shown in this chapter, the averaging window affects how the agents form their expectations responding to the future uncertainty. It seems important to reflect this feature when we study the optimal policy under AIT. Second, most literature including this chapter compares two different economies: one under IT vs the other under AIT. On the contrary, the transition from IT to AIT has been rarely studied. Understanding the dynamics during the transition period would enhance the understanding of AIT further. I leave these topics for future research.

CHAPTER 2

Identifying the effects of government spending shocks with a credit cycle

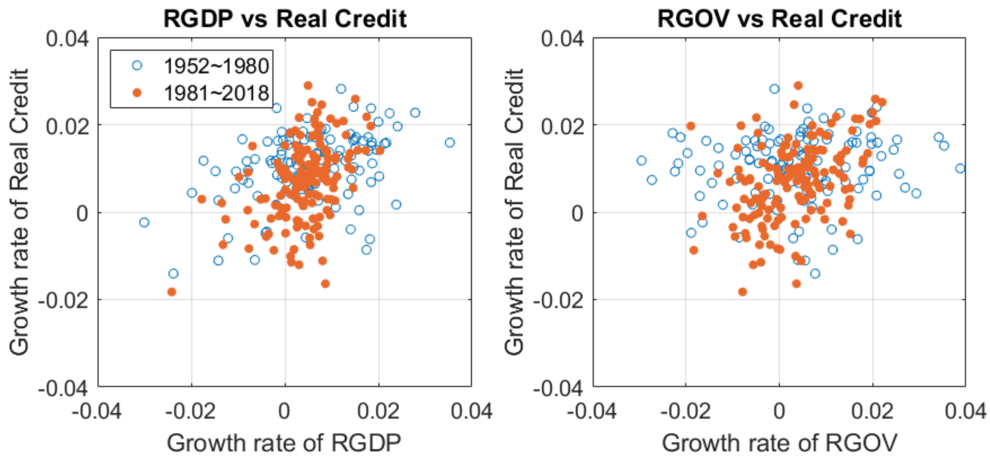
2.1. Introduction

Recently documented two crucial facts are that the correlation between credit and real variables has become more significant over the century and that there do not exist universal fiscal multipliers. Despite abundant research on each topic, empirical attempts to combine both are scarce. This chapter tries to fill this gap by estimating the effects of government spending shocks conditional on the credit cycle.

The upper panel in Figure 2.1 shows a scatter plot of real GDP and real credit in terms of growth rate. The hollow blue circles represent the period from 1952 to 1980 and the orange circles from 1981 to 2018. The relationship between the real GDP and real credit appears to have not changed significantly over the two periods. The lower panel displays the relationship between real government spending and real credit. As shown in the figure, they seem to correlate more positively. Numerically speaking, correlations between real GDP and real credit are 0.39 and 0.42 for before and after 1980 samples, respectively. As the first row of the figure suggests, the values have not changed a lot.

On the contrary, the correlation between real government spending and real credit rose from 0.12 to 0.40. This increase in the relationships suggests one possibility: the systematic responses of fiscal policies to innovations in the credit market. That is, one can imagine that the flow of real credit could have some power to predict the government spending shocks. If that is the case, controlling real credit is an important issue when we extract government spending shocks and measure the size of the fiscal multiplier.

Figure 2.1. RGDP, RGOV and RCREDIT



Note: The left panel plots (Real GDP, Real Credit) and the right panel shows (Real Government Spending, Real Credit) in terms of growth rate. The hollow blue circles represent the period from 1952 to 1980 and the orange circles from 1981 to 2018.

The empirical strategy in this paper is based on a nonlinear specification of the local projection method (Jordà (2005)) to estimate varying fiscal multipliers of variables of interest depending on the credit cycle. I define credit recession as times with quarters of negative growth rates of outstanding private-sector debt. Following Blanchard and Perotti (2002), exogenous shocks to government spending are identified as residuals of the series, which are not explained by lagged economic variables.

I modify this prototype identification scheme in two dimensions. One limitation of this type of shock is that they tend to be anticipated. To avoid this issue, Ramey (2011) construct a news series calculated as the differences between actual and forecasted government spending from the Survey of Professional Forecasters(SPF). Since the SPF series does not reflect the base year change of the series, however, the forecasted government spending does not correspond to the actual government spending exactly.

Instead of using this news series directly, I include the SPF data as one of the control variables when extracting the shocks from the data. By doing so, I circumvent the data consistency problem as well as the anticipation effect problem. Even after including the SPF data, I find that the identified shocks are predictable by credit data. I also include the credit data as a control in the identification scheme to purge anticipation effects that might emerge from this fact.

I first report the estimation results in the linear specification, which are summarized as follows: (1) The government spending shocks identified with credit have less persistent effects on economic variables than the shocks extracted without credit. For example, even if the output multiplier is larger than one on impact, it falls below one after three quarters so that the crowding-in effect does not last beyond medium to longer horizons. (2) Whether the credit data is included to identify the government spending shocks affects the dynamics of output, consumption, and investment, but not credit. (3) The government spending shocks loosen credit conditions in the economy at first, but they are tightened beyond the medium horizons, though the estimation is imprecise because of the wide confidence interval.

Next, I turn to the fiscal multipliers conditional on the credit cycle. Since about 79 percent of the sample period is in credit expansion, the dynamics of multipliers in that state are close to those from the linear specification. What draws attention is, thus, the movement of the multipliers in a credit recession.

In addition to the responses to the economic activity variables, I also explore the effects of government spending shocks on fiscal sustainability proxied by long-term government bond yield and/or debt-to-GDP ratio. The latter is a crucial empiric concern to address given the circumstances in which a lower bound constrains monetary policy, and the government debt level has elevated since the financial crisis. If discretionary fiscal measures worsen fiscal sustainability, the use of counter-cyclical fiscal policy would be limited so that we would be in trouble when fighting the next recessions.

The main findings are as follows: (1) Fiscal multipliers are dependent on the credit cycle. (2) Government spending shocks are more effective in a credit recession than expansion. For example, the on-impact output multiplier in credit recession is about 1.85, while in the expansion, it is about 0.92. (3) Whereas the government spending shocks seem to stimulate consumption in credit recession, investment tends to be less responsive to those shocks. This fact implies that a household's behavior is vital to understanding the state-dependent fiscal multiplier dynamics, at least for the credit cycle. In that sense, the conventional approach that puts more attention to household's behavior(see, for example, Galí et al. (2007), Eggertsson and Krugman (2012)) than firm's one is a good starting point to reveal the nonlinear dynamics behind the scene in the model.[1]

A mixed result about fiscal sustainability arises. The responses of the long-term interest rate to the government spending shocks suggest no evidence of a threat to fiscal sustainability because the interest rate does not rise. The variations of the debt-to-GDP ratio show that the ratio increases in good times but stays calm or falls slightly in bad times. This suggests that the government needs to prepare the future recessions in good time through fiscal consolidation rather than fiscal stimulus.

Several robustness checks are conducted in three dimensions: shock anticipation, credit cycle definition and unemployment as a control variable for the business cycle. I first show that the credit still anticipates the identified shocks without controlling credit even after including the variables related to the monetary policy. In addition, I find that the quantity credit variables have more predictive power than the price credit variables. For the state-dependent fiscal multiplier, the definition of the credit cycle is important. The estimation is repeated with 5 different definitions and similar results are found as in the baseline case. Lastly, credit cycle-dependent multipliers survive even when we control the business cycle using output or output gap instead of unemployment.

The remainder of the paper proceeds as follows. Section 2.2 reviews the related literature. Section 2.3 explains the data and methodology used in estimation. In section 2.4, I show why credit needs to be considered in shock identification and define credit cycle. Section 2.5 presents the estimation results from a linear model specification. Section 2.6 reports the

[1]Both of them assumed that the constraints are binding at all times, thus do not consider nonlinear dynamics.

fiscal multipliers conditional on credit cycle. Section 2.7 conducts several robustness checks and section 3.6 concludes.

2.2. Related literature

My work is related to the literature on fiscal multipliers, primarily based on the VAR-type approach. Identifying the exogenous fiscal shocks is challenging in this literature because they are correlated with macro variables contemporaneously. Thus, several methods have been developed as identification schemes.

Blanchard and Perotti (2002) address this problem by using external information on the elasticity of fiscal variables combined with the traditional Cholesky ordering identification scheme. They employ three variables(government spending, output and taxes) and define the government spending shocks as part of the data that is not explained or forecasted by the lagged variables. They find that government spending shocks raise GDP, consumption, and real wage. The papers following this approach, such as Perotti (2005), Galí et al. (2007), Bilbiie et al. (2008), also find the similar results.

Instead of using government spending data, Hall (2009) and Barro and Redlick (2011) use military spending as instruments for government spending. They argue that isolating multipliers of non-defense government spending is not optimistic because of their small variations and endogeneity. Their multipliers lie between 0.6 and 1. Some argue that the size of fiscal multiplier may also depend on the type of government spending. For example, Ilzetzki et al. (2013) report that the cumulative multiplier of public investment is about 1.5. In the theoretical literature, Sims and Wolff (2018) find that the average impact output multiplier for government investment varies little across states, albeit below 1, that is 0.9.

An alternative strategy is to construct directly exogenous fiscal shocks from different sources of information such as historical accounts. Ramey and Shapiro (1998) construct a dummy variable for military buildups and estimate the effects of war dates. Ramey (2011) creates a series of defense news, which is updated in Ramey and Zubairy (2018). They find the multipliers range from 0.6 to 1.2. Burnside et al. (2004) extend VAR using the war dates ordered first, and find government spending raises GDP and hours, although they did not specifically estimate multipliers.

Fisher and Peters (2010) construct a series of shocks based on the excess returns of defense contractor stocks instead of news. Forward-looking agents incorporate expectations of sales into their valuation of the stocks of these firms, thereby affecting the returns to holding these stocks. They estimate the government spending multiplier associated with increases in military spending to be about 1.5 over a horizon of 5 years. Ben Zeev and Pappa (2017) identify defense news shocks as the shocks that best explain future movements in defense spending over a horizon of five years, and that is orthogonal to current defense spending. Their cumulative output multiplier is 2.1 at 6 quarters. Other than the US data, Hussain and Liu (2018) construct government spending shocks for Canada using the narrative record, mostly the budget speech to identify the size, timing and principal motivation for all planned major government spending changes. They report that the multipliers for Canada range from 0.91 to 1.52.

This paper identifies the shocks based on the VAR-type approach using output, government spending, tax revenue, unemployment, and credit. I include unemployment following Barro and Redlick (2011) who argue that unemployment contains more information about the state of the business cycle over output. Unlike the existing literature, the credit variables are incorporated to control credit conditions as well as the anticipated component, which will be detailed below.

This paper is also related to a more recent strand of the literature estimating the state-dependent fiscal multipliers. Tagkalakis (2008) explores in a yearly panel of nineteen OECD countries from 1970 to 2002 the effects of fiscal policy changes on private consumption in recessions and expansions. In the presence of binding liquidity constraints on households, fiscal policy is more effective in boosting private consumption in recessions than in expansions.

Auerbach and Gorodnichenko (2012) find substantial differences in the size of spending multipliers in recessions and expansions with fiscal policy being considerably more effective in recessions than in expansions. They also show that controlling for predictable components of fiscal shocks tends to increase the size of the multipliers in recessions. In Auerbach and Gorodnichenko (2013), they confirm their earlier paper for a large number of OECD countries. Bachmann and Sims (2012) find similar results with the emphasis on the systematic response of confidence. That is, confidence rises following an increase in spending during periods of economic slack, and multipliers are much larger. The systematic response of confidence is irrelevant for the output multiplier during normal times but is critical during recessions. Fazzari et al. (2018) find that the government spending multiplier is larger and more persistent whenever there is considerable economic slack. Using capacity utilization as the state variable, they find that the estimated multiplier is large for a low-utilization regime that accounts for more than half of the sample observations from 1967 to 2012 according to the estimated threshold level. Caggiano et al. (2015) also show that fiscal spending multipliers in recessions are greater than one but not statistically larger than those in expansions. While these articles are using nonlinear VAR methods, analyses based on nonlinear local projection are increasing. For instance, Owyang et al. (2013) and Ramey and Zubairy (2018) employ this method to estimate the state-dependent fiscal multiplier of defense news shocks. They find no evidence favoring larger multipliers in slacks for the US.

Besides the business cycle, few papers explore the output multipliers in the zero lower bound(ZLB) periods. Crafts and Mills (2013) find that the government-expenditure multiplier was in the range of 0.3 to 0.9 even during the period when interest rates were at the lower bound in the United Kingdom, 1922-1938. Ramey and Zubairy (2018) shows a multiplier is above unity during ZLB periods for the post-war sample. Miyamoto et al. (2018) find more strong evidence that the output multiplier is higher in ZLB periods than that in the normal periods using Japanese data. This result is in line with one from the theoretical literature on ZLB. Among them are Eggertsson (2011), Eggertsson and Krugman (2012), Christiano et al. (2011), Woodford (2011) and Leeper et al. (2017).

Our paper is different from the ones mentioned above because we focus on the credit cycle rather than the business cycle or ZLB episodes. The literature in this area is rapidly growing. Among them are Corsetti et al. (2012), De Cos and Moral-Benito (2016) and Ferraresi et al. (2015)[2]. There are two papers that are closely related to the present paper: Borsi (2018) and Bernardini and Peersman (2018). Borsi (2018) studies the differences between fiscal multipliers in OECD economies across the credit cycle. He finds that expansionary fiscal policies result in large multipliers during credit bust episodes, which is about 2.69 for the mean response over three years. In contrast, the average multiplier in credit expansion is only 0.03, and statistically significant. He follows Auerbach and Gorodnichenko (2013) for shock identification and constructs fiscal policy shocks using government spending forecast errors[3]. We show in Section 2.4 that such a forecast error series is predicted by credit. Thus, instead of using those series as policy shocks, we identify the fiscal shocks by projecting government spending on macro variables as well as forecast variables. He defines the credit states based on a smooth transition function, which is commonly used in the literature. As shown in Alloza (2017), however, this method is vulnerable to the information used to determine the current state of the economy. Considering this, we define the credit cycle based on the peak-trough turning point method. Similarly, Bernardini and Peersman (2018) find that government spending multipliers are considerably larger in periods of private debt overhang using state-dependent local projections and historical US data. In particular, while multipliers are below or close to one in low private debt states, they find significant crowding-in of private spending in periods of debt overhang, resulting in much larger multipliers than one. They define the state of the economy as periods when ratios of private debt to gross domestic product (GDP) were respectively above and below trend, which is also employed by Schularick and Taylor

[2]See Section 2.6 for the details of these papers.

[3]Specifically, the shocks are computed as the difference between actual, first-release series of the government spending growth rate and the forecast series prepared by the OECD's professional forecasters.

(2012). Instead, we define the states based on the more direct measure, credit itself, and explore the multipliers when the credit is contracted and expanded[4]. Another difference from us is that they do not control for expected changes in government spending in the shock identification scheme[5].

More recent research on the state dependence on fiscal multiplier raises the possibility that the results from the literature might be fragile to small changes in specification. As mentioned before, Alloza (2017) shows that the result from Auerbach and Gorodnichenko (2012), which is one of the most seminal papers in this literature, could be reversed conditional on the information used to define the states. Barnichon et al. (2022) show that the contractionary multiplier is above one and the expansionary multiplier is substantially below one regardless of the state of the cycle. Keeping this caveat in mind, now we move to explain our data and methodology.

2.3. Data and Methodology

2.3.1. Data. This study makes use of US quarterly data for the period between 1981:3 and 2018:4. Data for real GDP, government spending, tax revenue, private consumption, private investment, GDP deflator, consumer price index, unemployment rate, credit, 10-year Treasury maturity rate and public debt to GDP ratio come from FRED. Government spending refers to government consumption expenditures and gross investment. Private consumption is the sum of non-durable goods and services expenditures. Private investment is the sum of durable goods and private nonresidential fixed investment expenditures. A series of credit to the non-financial private sector is constructed by the debt securities and

[4]Bernardini and Peersman (2018) define economic states based on a debt burden of the private sector and use the Debt-to-GDP ratio as a proxy for it. By contrast, we describe the states according to credit supply from banks and use credit data as a direct measure of the states.

[5]The advantage of this approach is the usage of long-period sample data spanned from 1919 :1 to 2013:4. Reported by Ramey (2011), though, such identified shocks are likely to be anticipated by professional forecasts and the narrative approach shocks. We take this anticipation effects seriously and decide to sacrifice the data before 1980.

loans of households and non-financial businesses. All variables are per capita and deflated by the GDP deflator except real GDP.

For the forecast data of government spending, we use the Survey of Professional Forecasters(SPF) from Philadelphia Fed. A possible alternative is Ramey's defense news series. The reason why we do not use this series is that, as Ramey (2011) pointed out, this series is much less informative for the most recent period. From 1981:3 to the present, the forecasters predict real federal spending. In period t-1, the forecasters predict the real federal spending for the period t-1 and t with I_{t-2}, which means information set in period t-2. Therefore, we can construct one-quarter-ahead forecast $F_{t-1}\Delta lnG_t$ for the current period growth rate of government spending, where $F_{t-1}\Delta lnG_t$ denotes the forecast of the quarterly growth rate of per capita government spending of period t made in period t-1. To control the expected component in government spending shocks, we use this variable as one of the control variables when we extract the shocks.

There are two reasons why I choose 1981:3 as a start date for our data. First, it is for data consistency. The SPF provides the forecast series of real federal spending from that date. Even though it provides a forecast of nominal defense spending from 1968:4 to 1981:2, the subject of the forecast is different before and after 1981:3. Second, several articles, for example Perotti (2005), report that the effects of fiscal shocks change around 1980s[6]. That is, before 1980, government spending has its strong effects so that GDP and private consumption increase after a spending shock. On the contrary, after 1980, GDP and private consumption respond less following a spending shock and the government spending process become less persistent. By ruling out the data before 1980, we can abstract from the sample selection effects: even though our estimated multipliers are higher than 1, they might not be because of the sample period we use. Considering these facts, we restrict our sample period to 1981:3-2018:4.

[6]Brückner and Pappa (2012) show that the responses of unemployment to expansionary expenditure shocks differ before and after the 1980s.

2.3.2. Methodology. Following the literature on a state-dependent fiscal multiplier, such as Ramey and Zubairy (2018) and Miyamoto et al. (2018), we estimate impulse-responses and multipliers of variables of interest with the local projection method introduced by Jordà (2005). This method estimates those by directly projecting a variable of interest on the government spending shocks as well as lagged macroeconomic variables typically hired to control the goods market, labor market and monetary policy.

While this approach does not impose any restrictions on the dynamics of impulse responses, it tends to become less precise and erratic at longer horizons. In addition to that, as shown below, the instrumental relevance of the shocks to government spending becomes weaker beyond the medium-term horizons when we estimate the multipliers. For these reasons, impulse responses and multipliers are reported for only 8 horizons throughout the paper.

To identify the unexpected government spending shocks, we first estimate the following linear model:

$$\Delta lnG_t = \alpha_0 + \alpha_1 F_{t-1}\Delta lnG_t + \psi(L)z_{t-1} + \epsilon_t \tag{2.1}$$

where ΔlnG_t is the log difference of government spending, $F_{t-1}\Delta lnG_t$ is the one-quarter-ahead forecast of ΔlnG_t, z_{t-1} is a vector of control variables, $\psi(L)$ is a polynomial in the lag operator, and ϵ_t is the identified government spending shock.

Following the spirit of Blanchard and Perotti (2002), we assume that government spending does not react contemporaneously to changes in economic activity. The assumption is motivated by the presence of decision and implementation lags. At least for the high-frequency data, such as quarterly data, this seems innocuous[7]. Since the SPF forecast data does not reflect the base year changes in the national income and product account, it does

[7]This is still widely accepted assumption in the literature. For example, Mertens and Ravn (2014a) mention that of the restrictions imposed by Blanchard and Perotti (2002), the current assumption seems the least questionable.

not correspond exactly to the dependent variable in Equation (2.1). Considering this, we include the forecast data as one of the control variables instead of constructing a series of forecast errors like Ramey (2011). This approach is also recently taken by Miyamoto et al. (2018) using Japanese data.

A vector of control variables, z_{t-1}, contains the growth rate of output, the growth rate of government spending, the growth rate of tax revenue, the growth rate of credit and the unemployment rate[8]. We add four lags of the control variables in the regression and scale the identified shocks so that they are measured as a percent of GDP. That is, we multiply the extracted shocks by the lagged ratio of government spending to GDP, $\frac{G_{t-1}}{Y_{t-1}}$. We refer to this shock as a baseline government spending shocks. We repeat the same procedure without credit terms in control variables. We call the latter shocks the predictable shocks because, as we will see below, they are predicted by the lagged credit values.

With the estimated government shocks in hand, now we can estimate the impulse responses of the variables of interest. The Jordà method is executed by estimating a series of regressions for each horizon h for each variable. That is, we estimate

$$x_{t+h} = \beta_{0,h} + \beta_{1,h} shock_t + \psi_h(L) z_{t-1} + \epsilon_{t+h} \tag{2.2}$$

for $h = 0, 1, 2, \cdots$. x_{t+h} is a variable of interest in horizon h[9], $shock_t$ is the series of government spending shocks identified from Equation (2.1), $\psi_h(L)$ is a lag operator. Then, $\beta_{1,h}$ gives the response of x at time $t + h$ to the shock at time t.

We can construct impulse responses of x as a sequence of the $\beta_{1,h}$ estimated in a series of Equation (2.2). One advantage of local projection is that it is permissible to use different control variables in each Equation. Therefore, depending on the independent variable x,

[8]In this baseline specification, monetary policy is not controlled. In section 2.7, we estimate the shocks with inflation and effective federal funds rates and check the shock anticipation.

[9]x_{t+h} is expressed as the percentage change of variable x between $t-1$ and $t+h$ normalized by GDP_{t-1} for real GDP, government spending, consumption, investment and real credit. For price indices, x_{t+h} is simply expressed as the percentage change of variable x between $t-1$ and $t+h$. For unemployment rate, x_{t+h} is expressed as the percentage point change of variable x between $t-1$ and $t+h$.

we can use different control variables. As benchmark controls, we include the growth rate of government spending, the growth rate of tax revenue, the growth rate of credit, and unemployment.

Note that to control the business cycle, we hire the unemployment rate rather than the growth rate of GDP or output gap[10]. As shown in Appendix B.1, the unemployment rate captures the output gap movement quite well. Note also that in order to control credit conditions in the economy, the growth rate of credit is included. For the variables other than output, we further include the lagged dependent variables in addition to the benchmark controls as controls.

To estimate multipliers, we compute the following regressions for each horizon h:

$$\sum_{j=0}^{h} x_{t+j} = \beta_{0,h} + M_h \sum_{j=0}^{h} \frac{G_{t+j} - G_{t-1}}{Y_{t-1}} + \psi_h(L) z_{t-1} + \epsilon_{t+h} \tag{2.3}$$

using $shock_t$ as an instrument for $\sum_{j=0}^{h} \frac{G_{t+j}-G_{t-1}}{Y_{t-1}}$. $\sum_{j=0}^{h} x_{t+h}$ is the sum of a variable of interest from t to $t+h$ and $\sum_{j=0}^{h} \frac{G_{t+j}-G_{t-1}}{Y_{t-1}}$ is the sum of government spending from t to $t+h$ normalized by output. M_h is the cumulative multiplier and its standard error is estimated directly from IV regression.

To estimate state-dependent impulse responses and fiscal multipliers, we need to modify the linear specification non-linearly. Local projection method is easily adapted to this change. To estimate state-dependent impulse responses, we estimate a series of regressions for each horizon h as follows:

$$\begin{aligned} x_{t+h} = & I_{t-1}\left[\beta^A_{0,h} + \beta^A_{1,h} shock_t + \psi^A_h(L) z_{t-1}\right] \\ & + (1 - I_{t-1})\left[\beta^B_{0,h} + \beta^B_{1,h} shock_t + \psi^B_h(L) z_{t-1}\right] + \epsilon_{t+h} \end{aligned} \tag{2.4}$$

[10]For example, Barro and Redlick (2011) argue that the unemployment rate is a more suitable variable relative to the growth rate of GDP to capture the business cycle of the economy. Also, Ramey and Zubairy (2018) use the unemployment rate as the indicator of the slack instead of GDP growth. In section 2.7, we conduct robustness checks with the growth rate of GDP and output gap.

where I_{t-1} is a dummy variable that indicates the state of the economy when the shock hits.[11] Thus, $\beta^A_{1,h}$ and $\beta^B_{1,h}$ are the response of the variable x at horizon h in state A and B, respectively. For the estimation of multiplier, we can modify Equation (2.3) to accommodate state dependence in the same manner. Thus, we estimate

$$\begin{aligned}\sum_{j=0}^{h} x_{t+j} =& I_{t-1}\left[\beta^A_{0,h} + M^A_h \sum_{j=0}^{h} \frac{G_{t+j}-G_{t-1}}{Y_{t-1}} + \psi^A_h(L)z_{t-1}\right] \\ &+ (1-I_{t-1})\left[\beta^B_{0,h} + M^B_h \sum_{j=0}^{h} \frac{G_{t+j}-G_{t-1}}{Y_{t-1}} + \psi_h(L)^B z_{t-1}\right] + \epsilon_{t+h}\end{aligned} \tag{2.5}$$

Similarly, M^A_h and $M^B_{,h}$ are the cumulative multipliers of the variable x at horizon h in state A and B, respectively.

2.4. Credit cycle

This section demonstrates why we need to take credit into account when we extract the government spending shocks from the data. After that, we define the credit cycles that we will use in the state-dependent fiscal multiplier estimation.

As emphasized by the previous literature, such as Ramey (2011) and Miyamoto et al. (2018), controlling for the expected change of government spending is crucial because rational agents can change their behavior corresponding to the forecast from the news or economic data before it materializes. The variables they concerned are military news or government spending forecast data from the profession. However, it is natural to extend this logic to any variables that have predictive power for government spending shocks.

To test this conjecture formally, we perform Granger causality tests between various variables, including the real credit and the government spending shocks derived from Equation (2.1) without real credit as a dependent variable. In addition to real credit variables, we

[11]Following the literature, we use the lagged economic state in order to avoid considering any effects from government spending shocks today to the current state of economy.

also check if Ramey's defense news series[12] can predict our extracted government spending shocks to get around the expected shocks problem. Note that we already used the Survey of Professional Forecasters for real government spending forecasts to control anticipation effect. Thus we expect that Ramey's news shocks would not Granger-cause our shocks.

Table 2.1 shows the results, and they confirm our conjecture. Real credit Granger-cause extracted government spending shocks(first row), which implies that the extracted government spending shocks without controlling real credit are forecastable. Since our shocks are identified by using forecast information, though, Ramey's defense news series does not Granger-cause the government spending shocks(second row). We also check if government spending shocks can Granger-cause real credit and it turns out that they do not (third row). Finally, we check if real credits Granger-cause government spending shocks identified with real credit information, and we can not reject the null hypothesis that real credits do not Granger-cause the extracted shocks with a p-value of 0.912.

Table 2.1. Granger Causality Tests

Hypothesis tests	p-value
Does credit Granger-cause government spending shocks? 1983:4-2018:4	Yes(0.000)
Do Ramey-News shocks Granger cause government spending shocks? 1983:4-2013:4	No(0.429)
Do government spending shocks Granger-cause real credit? 1983:4-2018:4	No(0.130)

Note: Government spending shocks were estimated by regressing the first difference of log real per capita government spending on 4 lags of itself, the first difference of log real per capita GDP, the first difference of log real per capita tax revenue, the unemployment rate. We use 4 lags for all Granger causality tests. The Ramey-news regression was estimated from 1983:4 to 2013:4 because the news data was only available for that period. For the other regressions, the data covers 1983:4-2018:4. The values in the parenthesis are p-values of the tests.

One may wonder if this arises because of our identification scheme from Equation (2.1). Do our results survive with differently identified shocks? For example, Ramey (2011) constructs the news series based on the difference between the growth rate of realized and SPF government spending from period t-1 and t. Auerbach and Gorodnichenko (2012) construct

[12]The data was extended to 2013:4 in April 2014 and is available on Ramey's website

a forecast series of government spending using Greenbrook as well as SPF, then extract unanticipated government spending innovations which are orthogonal to this series. Thus, we need to check also if credit still Granger-causes government spending shocks from the literature.

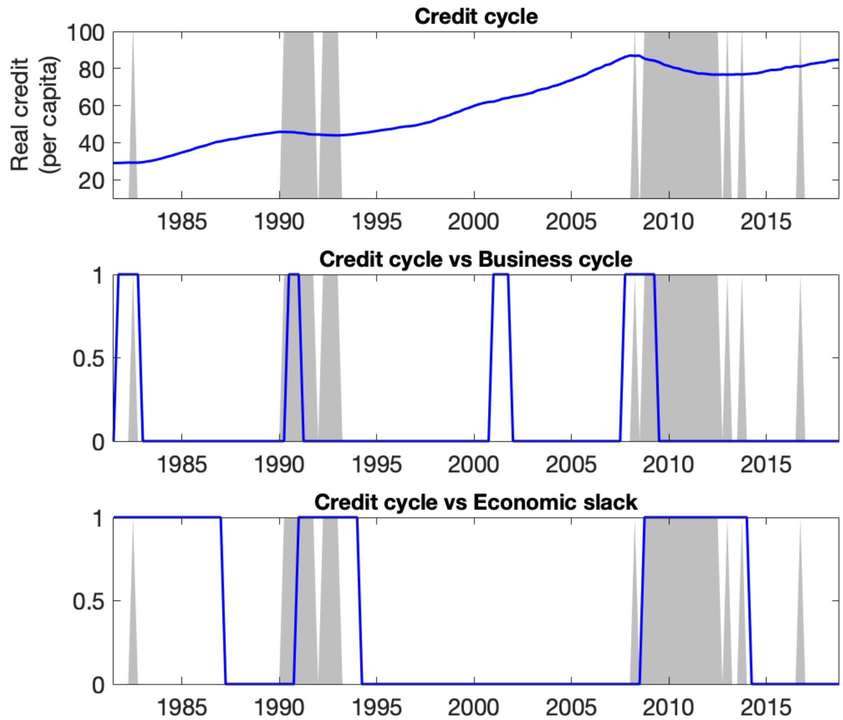
We first take Ramey (2011)'s news series as shocks and run the Granger-causality test. We find that credit still Granger-causes the shocks. For Auerbach and Gorodnichenko (2012) case, we identify government spending shocks using their forecast series as the one-quarter ahead forecast, $F_{t-1}\Delta lnG_t$, in Equation (2.1) and conduct the test. The result does not change[13]. All of these facts imply that controlling credit is crucial when we try to identify unexpected government spending shocks. If we fail to take into account this fact, we may deduce the wrong causal effects of government spending shocks because the shocks may contain forecastable components.

Now, we are in a position to define the credit cycle. Reinhart and Rogoff (2009), Jordà et al. (2013) among others find that financial-crisis recessions are more severe than normal recessions. From this fact, we can imagine that the effectiveness of fiscal policy also could differ conditioning on the credit cycle. However, most literature on state-dependent fiscal multipliers focuses on the traditional business cycle or monetary policy regime and puts less emphasis on the credit cycle. Since financial-crisis recessions and normal recessions exhibit different dynamics, fiscal multipliers conditioning on the credit cycle might be not identical to those on the business cycle.

I define credit recessions as contractionary episodes of credit and credit expansions as expansionary episodes of credit. This approach is equivalent to the dating of peaks and troughs used by NBER to define economic recession and expansion, though we do not take the persistence of the state into account. That is, I allow the economy to be in credit recessions or expansions only for 1 quarter. Given the relatively short sample period, we

[13]For the former case, we use the data spanned 1982:4-2018:4 and p-value is 0.01. For the latter case, the data covers 1968:1-2010:3 and p-value is 0.00.

Figure 2.2. Credit Cycle vs Economic Slack



Note: The shaded areas represent credit recessions for all three panels. The blue line in the first row plots real credit per capita, whereas the line in the second row corresponds to the business cycle recessions. The blue line in the bottom plots economic slack, which is defined as the states when the unemployment rate is above 6.5 percent. The value of 1 means the economy is in the credit recession and 0 in the credit expansion.

can not have sufficient episodes of credit recession for estimation. By allowing the 1-quarter state, I can secure a more extended recession episode.

The first row of Figure 2.2 plots real credit per capita from 1982:4 to 2018:4. Roughly speaking, we have two significant credit recessions during the sample period. The early 1990 recession lasts about 12 quarters and the credit contracts by 4.2 percent over the period. The second recession lasts about 20 quarters, and the credit decreased by 11.9 percent during the episode. Note also that the longer the expansionary episodes are, the longer and severer the following recessions are. These results echo Jordà et al. (2013).

For the comparison purpose, in the second row of Figure 2.2, we plot the credit cycle and the business cycle simultaneously. The NBER dates for the business cycle are used. They do not overlap a lot with each other. In addition, while the business cycle recessions do not last more than four quarters, the credit cycle recessions last much longer. The correlation between the credit cycle and the business cycle is about 0.19 over the sample period. This low correlation important in the sense that the fiscal multipliers conditional on the credit cycle might not be driven by business cycle dependency of the fiscal multiplier.

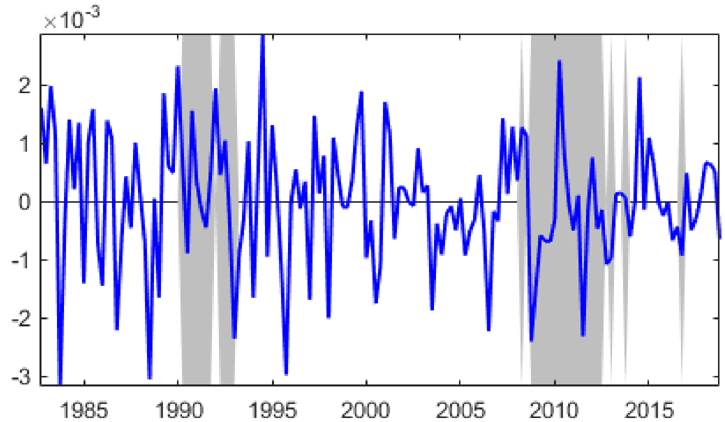
The economic slacks is also depicted following Ramey and Zubairy (2018). They define economic slack as a period when the unemployment rate is above 6.5 percent. The last row of Figure 2.2 plots the credit cycle and economics slack simultaneously. The economy has experienced 3 slack states. While the first slack that occurred in the early 1980s does not coincide with the credit recessions, the last two slack episodes overlap with credit recessions. This alludes to elevated interaction between real and financial variables. We can also see that credit recessions precede economic slacks 2 or 3 quarters ahead since the late 1980s.

2.5. Results from Linear specification

In this section, we show the identified government spending shocks and test their instrument relevance for estimation. To get a sense of how differently the economic variables respond to the shocks identified with and without credit, we first report the estimated multipliers of variables of interest in the linear model. That is, our estimates in this section do not condition on the state of the economy.

2.5.1. Identified shocks. Figure 2.3 plots the baseline shocks from Equation (2.1). The shocks are volatile over time, and active variation occurs regardless of the states of the economy. Even though we have relatively small episodes of credit recession, the shocks are well distributed over the cycles[14][15].

FIGURE 2.3. Identified government spending shocks



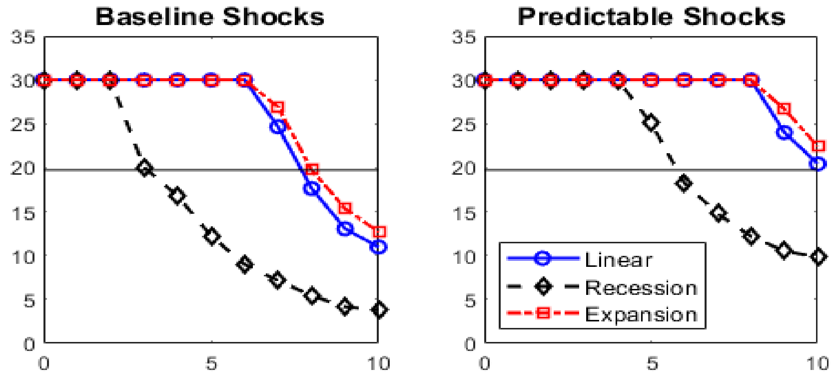
Note: The shocks are estimated from Equation (2.1). Shaded areas represent credit recessions.

Next, we test the instrumental relevance of our shocks. The weak instrument test matters because the shocks are used as an instrument in Equation (2.3) to estimate the multiplier. Following the convention of the literature, such as Ramey and Zubairy (2018) and Miyamoto et al. (2018), we use Olea and Pflueger (2013) effective F-statistics and thresholds. Figure 2.4 shows the results. We use the output multiplier equation to report F-statistics. The horizontal solid black line is the 10 percent critical value(19.7) of testing the null hypothesis that the two-stage least squares bias exceeds 10 percent of the ordinary least squares bias.

The left panel plots F-statistics with our baseline government spending shocks with the credit cycle. The solid blue line with a circle shows statistics when the model is linear so that any states of the economy are not considered. While the black dashed line with diamond shows the results when we only use the shocks in credit recessions, the red dash-dotted line with square represents the results with the shocks only in credit expansions. Whereas the F-statistics of the linear and expansion cases fall below the threshold 7 quarters after shocks,

[14]Out of 28 quarters in recession, positive and negative shocks occur 10 and 18 times, respectively. In the expansion period, positive and negative shocks occur 61 and 56 times, respectively.
[15]

Figure 2.4. Weak instrument test of the shocks



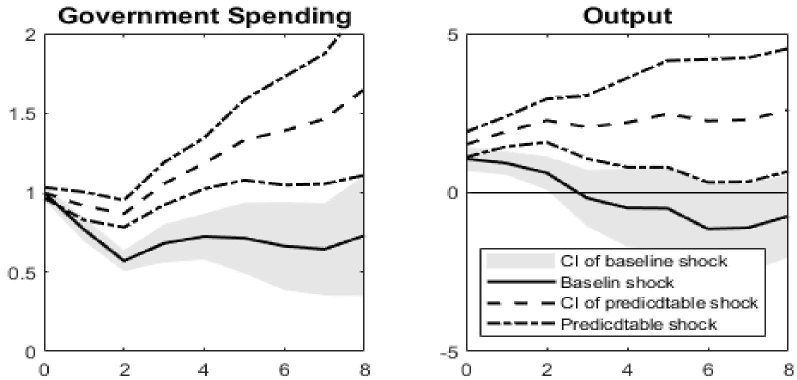
Note: The graph shows F-statistics, capped at 30, testing the weak instrument of the identified government spending shocks in the first stage estimation in Equation (2.3). The horizontal solid black line is the 10 percent critical value(19.7) of testing the null hypothesis that the two-stage least squares bias exceeds 10 percent of the ordinary least squares bias.

those of the recession case do 4 quarters earlier. This shows that identified shocks have high relevance at short horizons, which is consistent with the literature.

For the comparison, in the right panel of Figure 2.4, we report the test results with the government spending shocks identified without credit. Regardless of the model specification and the state of the economy, the F-statistics fall below the threshold later than the previous case. In the linear or expansion event, the statistics fall below the threshold after 10 quarters. In a recession case, it takes 5 quarters to go below the critical value. This implies that the exogeneity and non-predictability of our baseline shocks might come at the cost of instrument relevance. This is because our shocks are identified as the residual of current government spending, which is not explained by the other lagged control variables like Blanchard and Perotti (2002). If we rule out the credit variable as the control variable, the identified shocks would include components related to the lagged value of the credit. As shown in previous sections, credit and government spending are of high relevance. This could explain the high F-statistics in the predictable shock case.

2.5.2. Estimation result. We first describe the responses of government spending and output to an increase in government spending by 1 percent of output in period 0. Figure 2.5

FIGURE 2.5. Responses of Government spending and GDP



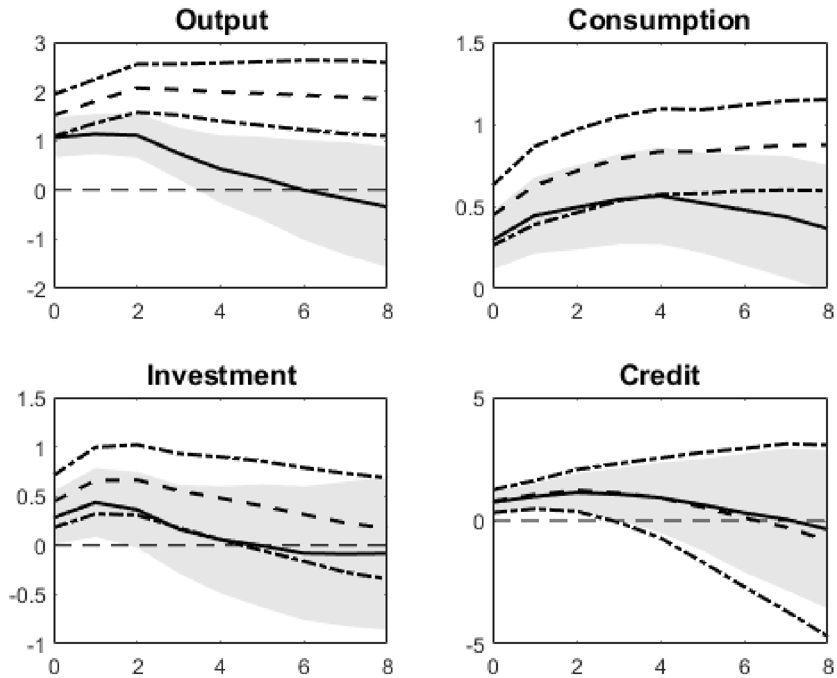
Note: Percent responses to government spending shocks by 1 percent of output. Solid lines and shaded areas are point estimates and one standard confidence interval responding to baseline shocks. Dashed lines and dash-dotted lines are point estimates and one standard confidence interval responding to predictable shocks.

shows the results. The solid lines in the figure depict the responses of government spending and output to our baseline shocks, which are extracted with credit being considered. The dashed lines of it plot responses when the shocks are identified without credit.

While the government spending rises on impact and persists at least up to 8 quarters regardless of the type of shocks, dynamics are quite disparate. In the case of the baseline shocks, the government spending falls slightly up to 2 quarters and hovers around 0.7 afterward. On the contrary, government spending steadily increases over time, responding to the predictable shocks. The dynamics of output seem much more different. Responding to the baseline shocks, output jumps on impact and decreases onward so that it turns negative at horizons longer than 3. In the predictable shock case, output jumps on impact and stays above 1 at least up to 8 quarters. Since the standard deviation is relatively large, though, the point estimates are not statistically significant at longer horizons. These dynamics carry over to the multipliers of output.

Figure 2.6 plots the cumulative multipliers of output, private consumption, investment, and credit for two types of shocks. The output multiplier in the baseline shock is 1.1 on impact, which is within the range of available estimates of 0.8 to 1.5 reported in Ramey (2019).

FIGURE 2.6. Cumulative fiscal multipliers



Note: Cumulative multipliers to government spending shocks by 1 percent of output. Solid lines and shaded areas are point estimates and one standard confidence interval responding to baseline shocks. Dashed lines and dash-dotted lines are point estimates and one standard confidence interval responding to predictable shocks.

After that, it falls below one and zero 2quarters and 6 quarters after shocks, respectively. In the predictable shock case, the output multiplier is 1.5 on impact, rises to 2.1 at horizon 2, and then falls slowly to 1.8 at horizon 8. These results show that the effects of the fiscal policy last longer in the latter case that the previous one. Therefore, if we do not take credit conditions into account when government spending shock is identified, the efficacy of fiscal policy could be over-estimated, especially at medium to longer horizons.

The upper-right panel of Figure 2.6 plots the cumulative multipliers of private consumption. They respond similarly to the shocks regardless of their types to 4 quarters, though the multipliers in case of the predictable shocks are higher than those in baseline shocks at all horizons. After fifth quarters, the multipliers in baseline case start falling while those in predictable case keep increasing.

The lower-left panel of Figure 2.6 depicts the cumulative multipliers of investment. While the point estimates in both shock cases exhibit similar dynamics, that is hump-shaped, the implications are quite different. The multipliers in the predictable shock case remain positive after 8 quarters so that the positive effects of government spending shocks linger at least for 2 years. In the baseline shock case, on the other hand, the multipliers peak at horizon 1 and turn negative after 5 quarters. Obviously, it seems that the distinct dynamics of consumption and investment across shocks cause different swings of output multipliers.

The lower-right panel of Figure 2.6 shows the cumulative multipliers of credit responding to each shock in period 0. Regardless of the type of shocks, the multipliers show almost the same dynamics, and they mimic the dynamics of investment, qualitatively. However, the estimation of credit is somewhat imprecise because of the wide confidence band.

Overall, the cumulative multipliers of macro variables show similar dynamics across the extracted government spending shocks with and without credit variable. The difference is detected in their amplitude and persistence. That is, the variations responding to the predictable shocks are larger and more persistent than those in the baseline case. This implies that unless we control for anticipation components from the credit, we might overestimate the effects of fiscal policy[16]. One notable thing is that inflation decreases on impact responding to the baseline shocks[17]. This results in stark contrast to the prediction from the standard NK model. We further discuss this topic in chapter 2.

[16]Perotti (2014) finds similar results. He shows that if there remains a fiscal foresight component in government spending shock, the estimated response to identified unexpected government spending shock has an expansionary or positive bias.

[17]See Appendix B.2 for the graphs.

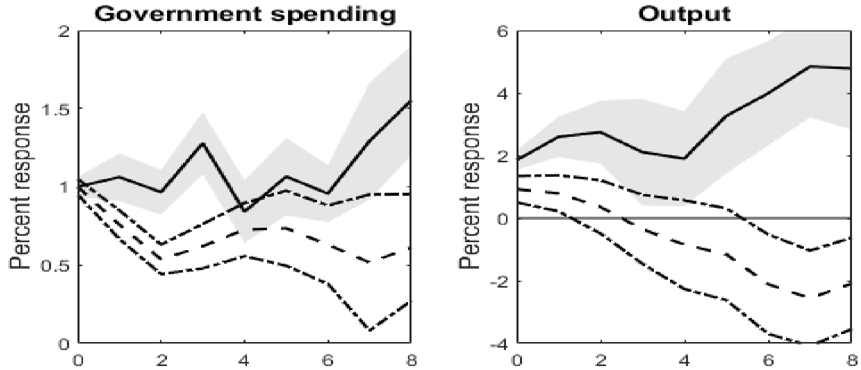
2.6. Fiscal multipliers conditional on credit cycle

Now, we turn to the state-dependent government spending multipliers responding to our baseline shocks. The related empirical literature mainly has estimated those values conditioning on the business cycles or ZLB. We instead focus on the credit cycle, which is defined in Section 2.4. We argued in the previous sections that it is important to take credit into account when we analyze the effects of government spending. Naturally, this also implies that the efficacy of fiscal policy may differ depending on the credit cycle. In this section, we report the fiscal multipliers of economic variables conditional on the credit cycle.

We first estimate the responses of government spending and output responding to an increase in government spending by 1 percent of output in period 0. The left panel of the figure 2.7 shows that the responses of government spending in credit recession and expansion diverge. That is, in bad time, the shocks become more persistent and potent so that the response at horizon 8 is even larger than that on impact. In good time, however, the responses decay from period 0 so that at horizon 8 the response is about half of that on impact. The responses of output exhibit the same pattern. In a credit recession, the response of output jumps to about 2 on impact and rises to below 5 at horizon 8. On the contrary, the responses of output in credit expansion rise to about 1 and decrease steadily up to around -2 at horizon 8. The on-impact multipliers in credit expansion are 0.92, and that in credit recession is 1.85, which is almost twice as large as the expansion multiplier.

Figure 2.8 plots the cumulative multipliers of output and credit. For the output case, whereas the cumulative multipliers in credit recession stay above 2 after government spending shocks hit the economy, those in credit expansion fall from period 0 and turn to negative after a year. Thus, the crowd-in effects of government spending shocks linger longer in bad time than in good time. Note that the on-impact multipliers in both states are statistically significant at the 5 percent level. Also, the differences between the two multipliers are noticeable. We can directly test the hypothesis that the multiplier in a recession is equal to

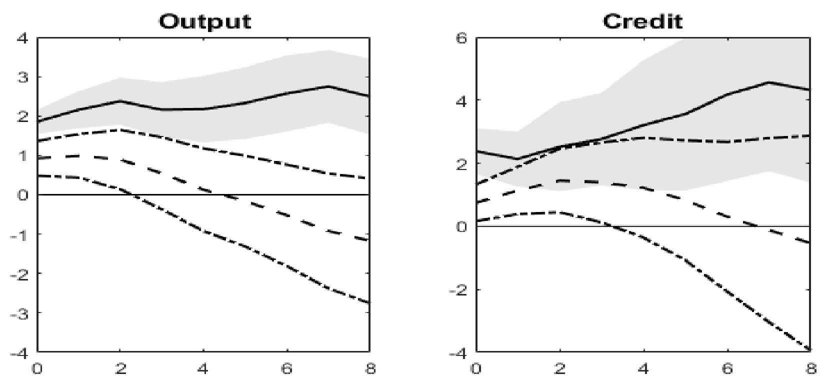
FIGURE 2.7. Responses ot Government spending and Output



Note: The solid line and the shaded areas are responses and one standard error bands in credit recessions. The dashed line and dash-dotted lines correspond to responses and one standard error bands in credit expansion.

that in expansion at all horizons from Equation (2.5). That is, we test $M_h^A = M_h^B$. The last column of the Table 2.2 reports the results at various horizons. Since the all HAC p-values but the value of 4 quarters are below 0.1, the differences are statistically significant.

FIGURE 2.8. Cumulative multipliers of Output and Credit



Note: The solid line and the shaded areas are responses and one standard error bands in credit recessions. The dashed line and dash-dotted lines are responses and one standard error bands in credit expansions.

Our results are in line with several articles that estimate financial-state-dependent fiscal multipliers. Corsetti et al. (2012) estimate fiscal multipliers conditional on financial crisis[18] for a panel of OECD countries and find that the on impact output multipliers in financial

[18]For the definition of the financial crisis, they follow the classification of Reinhart and Rogoff (2008).

Table 2.2. Cumulative multipliers of Output and Credit

	Output				Credit			
	Linear	Recession	Expansion	p-values	Linear	Recession	Expansion	p-values
On-impact	1.06	1.85	0.92	HAC:0.06	0.75	2.38	0.74	HAC:0.07
	(0.41)	(0.31)	(0.44)		(0.44)	(0.73)	(0.58)	
1 quarter	1.13	2.16	0.99	HAC:0.09	0.98	2.13	1.14	HAC:0.38
	(0.41)	(0.47)	(0.55)		(0.53)	(0.87)	(0.87)	
4 quarter	0.42	2.17	0.13	HAC:0.17	0.93	3.21	1.22	HAC:0.48
	(0.69)	(0.84)	(1.05)		(1.43)	(2.06)	(2.06)	
8 quarter	-0.34	2.49	-1.17	HAC:0.05	-0.35	4.32	-0.53	HAC:0.31
	(1.22)	(0.96)	(1.58)		(3.22)	(2.87)	(2.94)	

Note: The table reports the output and credit multipliers at different horizons in linear, credit recession, and credit expansion cases. The values in parenthesis are HAC standard errors. *p*-values are for the differences in multipliers between two states.

crisis and out of the crisis are around 2 and 0, respectively. Using Spain data, De Cos and Moral-Benito (2016) find that the on-impact multipliers in periods of banking stress and out of stress are 1.56 and 0.16, respectively. Ferraresi et al. (2015) also find that the multiplier is persistently higher than on in the tight credit regime and lower than one 1 the normal credit regime. They define the credit regime based on the spread between BAA-rated corporate bond yield and 10-year treasury constant maturity rate. While they use prices as a proxy for credit conditions, this article employs a more direct indicator of the credit cycle, namely the quarter-to-quarter change in private credit.

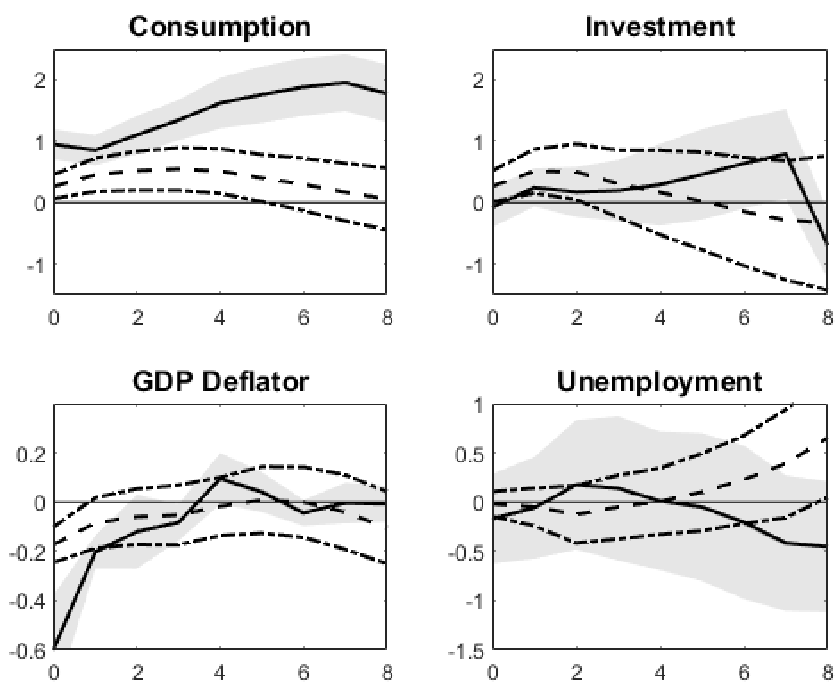
At least qualitatively, the cumulative multipliers of credit are similar to those of output. In a credit recession, the on impact multiplier is 2.38, 3.55 after 1 year, and 4.76 after 2 years. Thus, the effectiveness of government spending shocks in credit markets become potent. On the contrary, in credit expansion, the multipliers are hump-shaped and relatively muted. This result suggests that in a structural model, we have to consider the transmission mechanism via credits to understand the output dynamics correctly.

Next, we investigate the cumulative multipliers of consumption and investment. The first row of Figure 2.9 depicts them. The on-impact consumption multiplier in the recession is 0.95. After 1 quarter, it rises steadily and reaches to about 1.77 after 2 years. In expansion, consumption only increases by 0.26 percent on impact. After the multiplier increases to

0.51 in 1 year, the effect of government spending shocks on consumption diminishes so that in 2 years, the multiplier drops to about 0. The difference of the consumption multipliers between two credit regimes are statistically significant at the 5 percent level at almost all horizons(see Table 2.3, above). Since the development of consumption multipliers are similar to that of output, it seems that the consumption dynamics mainly drive the large multipliers of output to government spending shock.

The variation of investment confirms this conjecture. As the upper-right panel of Figure 2.9 shows, investment hardly responds to government spending shocks in recession. In expansion, the on-impact multiplier is 0.26, but the effects decay after 1 quarter. Moreover, the differences in multipliers are not statistically significant, which implies that the investment barely responds to government spending shocks regardless of credit cycles.

FIGURE 2.9. Cumulative multipliers of Consumption and Investment



Note: The solid line and the shaded areas are responses and one standard error bands in credit recessions. The dashed line and dash-dotted lines are responses and one standard error bands in credit expansions.

Table 2.3. Cumulative multipliers of Consumption and Investment

	Consumption				Investment			
	Linear	Recession	Expansion	p-values	Linear	Recession	Expansion	p-values
On-impact	0.27 (0.16)	0.95 (0.25)	0.26 (0.19)	HAC:0.03	0.28 (0.27)	0.10 (0.44)	0.26 (0.27)	HAC:0.76
1 quarter	0.36 (0.21)	0.85 (0.24)	0.45 (0.27)	HAC:0.28	0.43 (0.35)	0.03 (0.41)	0.51 (0.39)	HAC:0.43
4 quarter	0.29 (0.29)	1.62 (0.41)	0.51 (0.36)	HAC:0.02	0.06 (0.54)	-0.19 (0.70)	0.16 (0.74)	HAC:0.73
8 quarter	-0.10 (0.52)	1.77 (0.46)	0.06 (0.50)	HAC:0.00	-0.08 (0.78)	-0.34 (0.86)	-0.25 (1.01)	HAC:0.94

Note: The table reports the consumption and investment multipliers at different horizons in linear, credit recession and credit expansion cases. The values in parenthesis are HAC standard errors. *p*-values are for the differences in multipliers between two states.

Note that the shape of consumption and investment multipliers in credit expansion mimics that of credit multipliers in good time. However, the investment multipliers in credit recession are quite different from credit multipliers in bad time, though the consumption multipliers imitate the latter. Therefore, the mechanism by which additional money injected from the government works through a household's consumption. Also, it seems that in bad times, firms might make an investment decision based on other factors rather than credit conditions.

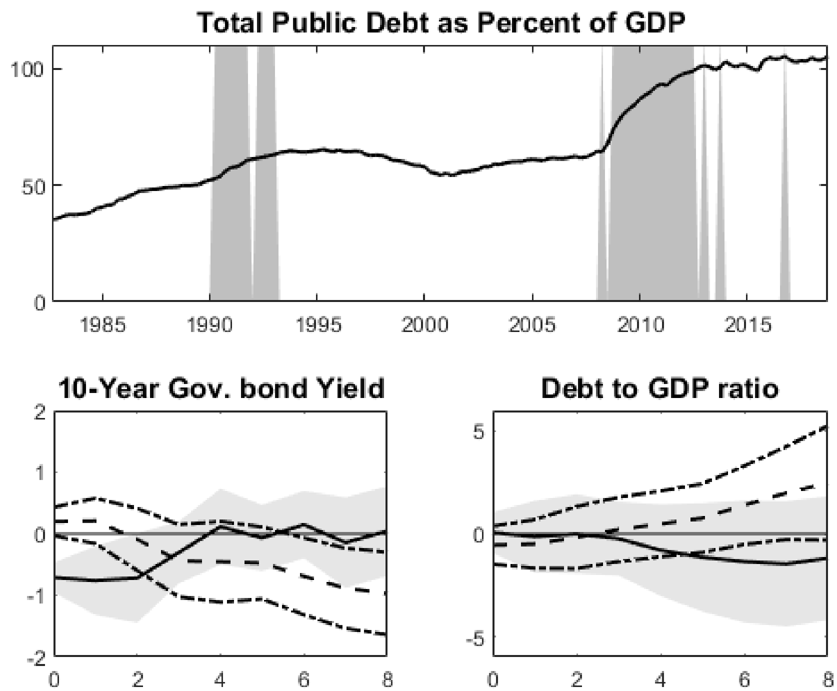
We also estimate the multipliers of GDP deflator and unemployment. In credit recession, GDP deflator falls by about 0.6 percent on-impact responding to a change in government spending by 1 percent of output, though it returns to around 0 in a year. The multipliers in the expansion are less volatile than those in the recession. On impact, GDP deflator decreases by 0.2 percentage point and returns to zero steadily over the horizons. The difference between the multipliers in the two regimes is only statistically significant on impact. Not surprisingly, the multipliers of unemployment mirror the movement of output multipliers.

Lastly, we turn to fiscal sustainability. Given the extended period of loose monetary and fiscal policy regimes, fiscal sustainability is important to fight future recessions. If the government spending shocks deteriorate fiscal sustainability, the abuse of fiscal policy should be limited. The upper panel of Figure 2.10 plots the total public debt as a percent of GDP.

Before the financial crisis, it has risen slowly but stood below around 70 percent. After the financial crisis, it jumped to above 100 percent and has remained there. This rise of debt-to-GDP ratio raises the concern about fiscal sustainability. Thus, we estimate the effects of government spending shocks on fiscal sustainability measured by long-run interest rates and debt-to-GDP ratio. The long-term interest rate is a proxy for a financing cost and debt-to-GDP ratio for a debt burden.

The lower-left panel of Figure 2.10 plots the cumulative multiplier of long-term interest rate proxied by 10-year Treasury maturity rate. We use the growth rate of GDP deflator and linear trend as controls as well as the benchmark controls. The linear trend is included to

FIGURE 2.10. Cumulative multipliers of Long-run interest rate and Debt-to-GDP ratio



Note: The solid line in the upper panel represents the debt-to-GDP ratio, and the shaded areas are credit recession periods. For the lower panels, The solid line and the shaded areas are responses and one standard error bands in credit recessions. The dashed line and dash-dotted lines are responses and one standard error bands in credit expansion.

capture the declining tendency of the interest rate. If the interest rate rises responding to the government spending shocks, it means higher financing cost so that the fiscal sustainability would be jeopardized. In a credit recession, the long-run interest rate decreases by 0.7 percentage point on-impact, which is significantly different from 0 at the 5 percent level. After that, it approaches 0 and hovers around 0 after 1 year. In credit expansion, the long-run interest rate slightly increases by about 0.2 percentage point, turns to negative after 2 quarters and falls to -1 percentage point at horizon 8. Therefore, the point estimates suggest that the government spending shocks rather enhance fiscal sustainability in both credit regimes. This result is similar to Auerbach and Gorodnichenko (2017), though their results are conditional on the business cycle. As they argued, the results imply that the market thinks of government intervention as a positive factor in fiscal sustainability. One caveat is that we are looking at US data whose sovereign credit rating is very high. That is, the results presented here seem sensitive to the sovereign credit rating.

The cumulative multipliers of debt-to-GDP ratio to a change in government spending by 1 percent of output are depicted in the lower-right panel of Figure 2.10. In a credit recession, the multipliers are close to 0 from 0 to 4 quarters and fall to around 1.2 percentage points in 2 years. Thus, like the long-run interest case, government intervention in bad time does not deteriorate the fiscal sustainability. On the contrary, the ratio rises in good time so that in 2 years, the ratio increases by about 2.5 percentage points. Since the government intervention in good time raises the debt-to-GDP ratio in the medium run, the aggressive fiscal policy could reduce sustainability. One lesson from this fact is that the government should make room to maneuver in good time, such as fiscal consolidation, so that they could implement the fiscal policy in a bad time to fight the coming future slumps.

One limitation of our empirical findings is that, in some cases, the estimates are not statistically significant because of wide confidence bands. Thus, the results should be interpreted as tentative. This reflects the fact not only that the data variation is limited, but also it involves a relatively short period. Even though the estimates are not sufficiently precise to make a clear inference, the evidence is strong enough to analyze the fiscal effects conditional on credit conditions.

2.7. Robustness

In this section, we conduct several robustness checks for potential problems. These are: (i) shock anticipation; (ii) definition of credit cycle; (iii) unemployment as a control variable for the business cycle . We look at each of them one by one.

2.7.1. Shock anticipation. In sectoin 2.4, we showed that the shocks identified without credit are anticipated by the credit. One may wonder if this is because we did not include the variables related to the monetary policy in the control variables of Equation (2.1). Thus, we add inflation and 3-month Treasury bill rates to the control variables and check the robustness of our results. As the table 2.4 shows, even after this change, the results survive and credit still has some power to predicts the shocks.

TABLE 2.4. Granger Causality Tests

Hypothesis tests	p-value
Does credit Granger-cause government spending shocks? 1983:4-2018:4	Yes(0.003)
Do Ramey-News shocks Granger cause government spending shocks? 1983:4-2013:4	No(0.634)
Do government spending shocks Granger-cause real credit? 1983:4-2018:4	Yes(0.012)

Note: Government spending shocks were estimated by regressing the first difference of log real per capita government spending on 4 lags of itself, the first difference of log real per capita GDP, the first difference of log real per capita tax revenue, the unemployment rate, inflation rate, 3-month tbill rate. We use 4 lags for all Granger causality tests. The Ramey-news regression was estimated from 1983:4 to 2013:4 because the news data was only available for that period. For the other regressions, the data covers 1983:4-2018:4. The values in the parenthesis are p-values of the tests.

Can we still anticipate the shocks based on price variables instead of quantity variables? Following Ferraresi et al. (2015), we employ the spread between BAA-rated corporate bond

Table 2.5. Credit vs Spread : Granger Causality Tests

	Credit/Spread	+GDP	+Unemp	+Tax rev	+Gov. spending
Credit	0.003	0.000	0.000	0.000	0.000
Spread	0.160	0.106	0.073	0.07	0.019

Note: Government spending shocks were estimated by regressing the first difference of log real per capita government spending on 4 lags of itself, the first difference of log real per capita GDP, the first difference of log real per capita tax revenue and the unemployment rate. We use 4 lags for all Granger causality tests. For all regressions, the data covers 1983:4-2018:4.

yield and 10-year treasury constant maturity rate[19] as a proxy for credit conditions and see if the spread can forecast the shocks. Table 2.5 displays the results. The first column reports the p-values of the tests between the shocks and credit/spread. The second column states the test results when we include GDP to the test. The following columns describe the same results in the same manner. As we can see, credit always has some power to predict the identified shocks regardless of the expansion of variable dimensions.

On the contrary, the predictability of spread counts on the number of variables used. With only spread or spread and GDP, spread does not Granger-cause the shocks at a 10 percent level. When unemployment rate and tax revenue are included, spread fails to Granger-cause the shocks at a 5 percent level. Only when the government spending is also included, the spread can forecast the shocks at the 5 percent level. Therefore, at least for our specification, the quantity variable has more predictive power than the price variable.

2.7.2. Definition of credit cycle. Instead of our baseline definition of the credit cycle, we can define it in different manners. In this subsection, we consider 5 alternatives:

(i) Define the cycles based on the peak-trough approach using credit to household data instead of credit to the private sector.

(ii) The economy is in the credit recession if the BAA spread is one standard deviation higher than the sample mean spread.

[19]Both Moody's seasoned BAA corporate bond yield(BAA) and 10-year treasury constant maturity rate(GS10) are recovered from the FRED.

(iii) Use a smooth logistic transition function

$$I(\theta_t) = \frac{exp(-\gamma\theta_t)}{1 + exp(-\gamma\theta_t)}, \quad \gamma > 0.$$

We use a backward MA filter of order 7 of credit growth rate for θ_t, which is normalized to zero mean and unit variance. γ is set to 1.5[20]. We define the economy is in the credit recession if $I(\theta_t) > 0.8$.

(iv) The setup is equal to the case (iii) except that now we use a centered MA filter of order 7. That is, we use the past as well as future information to determine the state of the economy. In (iii), we used only past information[21].

(v) Lastly, HP-filtered Debt-to GDP ratio with high smoothing parameter($\lambda = 1e7$) is used[22]. We divide the economy into two states, high and low debt instead of the credit recession and expansion. The high debt state is defined as the periods when the Debt-to-GDP is higher than a HP trend.

Appendix B.3 displays the graph which compares each credit cycle defined by the alternatives. Even though they do not coincide with each other, they exhibit similar patterns. However, the cycles derived from Debt-to-GDP are quite different from the others. This is because while this approach focuses on the debt burden of the household, others put more emphasis on how much credit is supplied by banks[23]. Therefore, it is natural to conjecture that the fiscal multipliers would be different from others.

[20] This calibration means that the economy spends about 25 percent of the time in a recessionary regime.

[21] As Alloza (2017) pointed out, MA filter could deliver very different multipliers depending on the information used to determine the current state of the economy. To check this concern, we use two different MA filters

[22] When we use a standard smoothing parameter, $\lambda = 1,600$, 72 quarters of the sample period is in the high debt state. Bernardini and Peersman (2018) also use high smoothing parameter($\lambda = 1e6$) as a baseline definition of debt overhang.

[23] For example, even though the household debt is low, if the income is also low, the debt burden could be high. It means that the economy could be in a high debt state when it is in the credit recession. This actually happened in the financial crisis. As shown in the last row of the figure in Appendix B.3, in that period, the economy is in the high debt and the credit recession state.

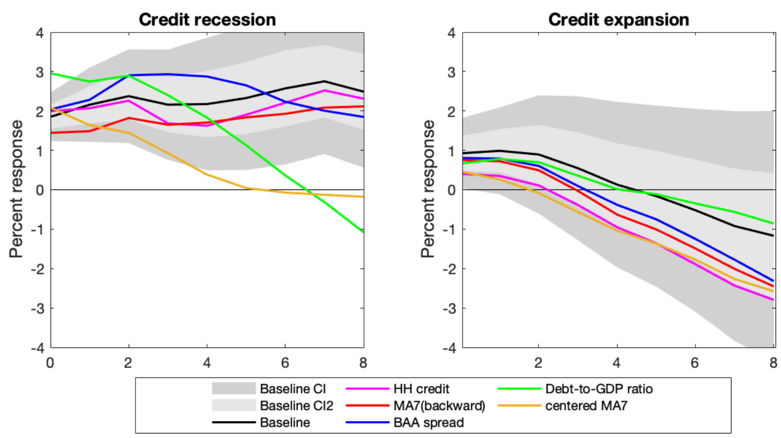
Table 2.6. Credit cycles

	Baseline	Credit to HH	BAA spread	bMA(7)	cMA(7)	Debt-to-GDP
Recession	32	40	39	39	36	54
	(21.3)	(26.7)	(26.0)	(26.0)	(24.0)	(36.0)
Expansion	118	110	111	111	114	96
	(78.7)	(73.3)	(74.0)	(74.0)	(76.0)	(64.0)

Note: This table reports the number of quarters in recession and in expansion out of sample period under each credit cycle definition. The values in the parenthesis represent the percentages. bMA(7) means backward MA(7) and cMA(7) means centered MA(7).

Table 2.6 shows the number of quarters in recession and expansion out of the sample period under each credit cycle definition. That in recession ranges from 28 to 54 quarters, which accounts for between about 20 and 25 percent of the sample period.

Figure 2.11. Cumulative multipliers under different credit cycles



Note: We estimate the multipliers with the baseline control. HH credit means the cycles are determined by the credit to the households. MA7(backward) means that the cycles are determined by a one-sided MA filter of order 7 that only uses past information. BAA spread means that the cycles are determined by BAA spreads. Debt-to-GDP means that the cycles are determined by HP-filtered Credit-to-GDP with a very high smoothing parameter(1e7). Centered MA7 means that the cycles are determined by a centered MA filter of order 7. The solid black line, the shaded areas and the darker shaded areas are responses, one standard and two standard error bands for the baseline results, respectively.

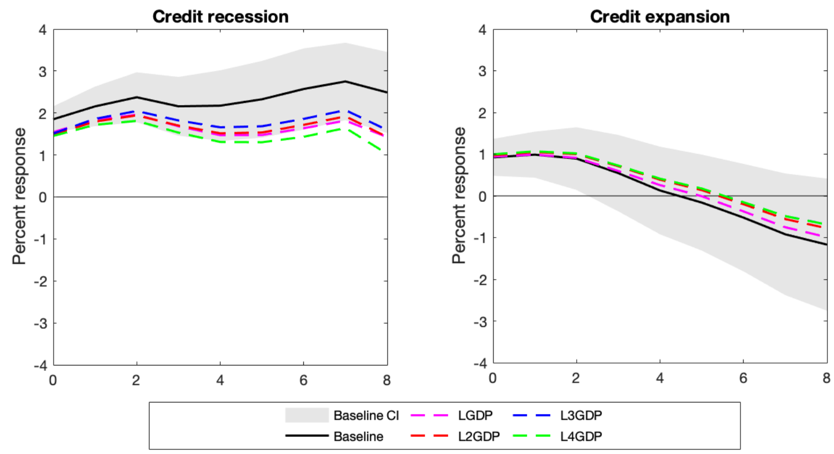
Figure 2.11 reports the estimated output multipliers based on various credit cycles defined above. We start with the credit recession case, which is shown in the left panel. The purple and blue lines show the results for the first two alternatives. Both of them suggest high and persistent multipliers and are in the one-standard confidence intervals. The red and yellow lines are for the backward and centered MA, respectively. Again, the red line(backward MA7) exhibits the high multipliers and well lies in the one-standard confidence intervals. Unlike this, the yellow line(backward MA7) shows that the multipliers decrease sharply after shocks and go below zero after 6 quarters, albeit a high on-impact multiplier. Lastly, the green line corresponds to the last alternative. It shows somewhat different movements as we conjecture: on-impact, the multiplier is higher than the baseline case, but it falls sharply 2 quarters after shocks so that the crowd-in effects do not last long.

The right panel displays the results for the credit expansion. Regardless of the definitions, the multipliers generate analogous movements. Although the newly estimated multipliers tend to be lower than the baseline levels, all of them lie in the one-standard confidence intervals. Interestingly, multipliers in a low debt state are similar to those in a credit expansion.

2.7.3. Unemployment as a control variable for the business cycle. In estimating responses or multipliers of variables, we control the business cycle using unemployment rates rather than the growth rate of output or output gap. One concern is that unemployment rates relatively move slower than the output. Thus, our specification might raise the possibility that the business cycle is not controlled appropriately.

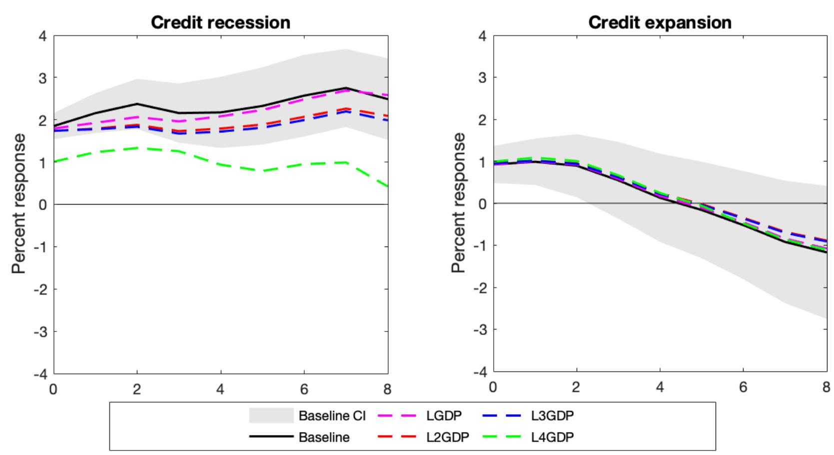
We first use the output gap as our proxy for a business cycle instead of the unemployment rate. We define the output gap as the ratio of a difference between the actual GDP and its time trend to the time trend. Following Ramey and Zubairy (2018), the real GDP time trend is estimated as a sixth-degree polynomial for the logarithm of GDP, from 1952:1 through 2018:4. Figure 2.12 reports the result. For the credit recession case, while the newly estimated multipliers tend to be smaller than the baseline case, they are within the confidence intervals. They are very close to the lower bound of one standard error band for almost horizons. Still, they lie well above one. For the credit expansion, we find similar multipliers regardless of the model specifications.

Figure 2.12. Cumulative multipliers of output with output gap



Note: We estimate the multipliers with the lags of the output gap as controls in addition to the baseline controls but the unemployment rate. LGap means the case when we add the lag of order 1. L2Gap means the case when we add the lag of order 2. L3Gap means the case when we add the lag of order 3. L4Gap means the case when we add the lag of order 4. The solid black line and the shaded areas are responses and one standard error bands for the baseline results.

Figure 2.13. Cumulative multipliers of output with output growth



Note: We estimate the multipliers with the lags of output growth rate as controls in addition to the baseline controls but the unemployment rate. LGDP means the case when we add the lag of order 1. L2GDP means the case when we add the lag of order 2. L3GDP means the case when we add the lag of order 3. L4GDP means the case when we add the lag of order 4. The solid black line and the shaded areas are responses and one standard error bands for the baseline results.

Figure 2.13 shows the results when we use the growth rate of output instead of the output gap. As shown in the right panel, in credit expansion, the multipliers seem to be not affected by the modified specification: the new point estimates almost are identical to the baseline result. This is also true in the credit recession, displayed in the left panel, for the first three lags. While the newly estimated multipliers are somewhat lower than the baseline case, they are all in the confidence intervals. However, for the lag of order 4, the point estimates fall significantly, even though the multipliers are above 1 for the first 4 periods.

2.8. Conclusion

Estimating the fiscal multipliers is important for policymakers to design fiscal packages. Before the Great Recession, the conventional wisdom was that there exists a multiplier that is applied to any circumstances regardless of the states of the economy. However, it is turned out that what we have thought as an unconditional multiplier is an average multiplier over economics states. If the policymakers stick to this average multiplier, the policy design would be misled, and the effects of the policy would not be exerted as expected. In that sense, estimating a state-dependent fiscal multiplier is crucial.

Responding to this idea, much work has been done of late to estimate the non-linear effects of fiscal multiplier empirically or theoretically. However, the focus was mainly on the case of the business cycle or zero lower bound, and less attention was paid to credit conditions in the economy. To fill this gap, we analyze the case of the credit cycle in some detail. We first argue that credit needs to be considered in government shock identification scheme. Otherwise, the extracted shocks are anticipated by the credit so that the estimation would be biased. With these identified shocks, we estimate the average multipliers and find that they have less persistent effects on output than the shocks identified without credit. This less persistent effect comes from the dynamics of investment rather than consumption. Finally, we report the non-linear effects of fiscal shocks across the credit cycle. Our results indicate that the fiscal multiplier might be large and above 1 during the credit recession, and the household's behavior mainly drives this. Regarding fiscal sustainability, it seems that government spending shocks do not threaten them.

Although the empirical literature provides sufficient evidence on state dependence in fiscal multipliers, whether it is business cycle-dependent or credit cycle-dependent, there is a shortage of theoretical literature that supports them. Thus, the natural step to move forward from this paper would be to figure out a structural explanation of why fiscal multipliers differ across credit cycles. Nevertheless, recently, there are few attempts to suggest the channels through which fiscal shocks affect the economy nonlinearly. Michaillat (2014) develops a model with search and matching friction in an otherwise standard New-Keynesian framework. He shows that an increase in public employment weakens the effectiveness of raising civil employment by rising labor costs. Canzoneri et al. (2016) explain the nonlinearity based on counter-cyclical variation in bank intermediation costs. In a recession, when the spread between bank deposit and loan rate is high, a fiscal stimulus decreases the spread so that more borrowing occurs. Shen and Yang (2018) show that downward nominal wage rigidity, which arises only in recessions, can generate business cycle-dependent government spending multipliers. McManus et al. (2018) also show that fiscal effectiveness can vary across the business cycle in a medium-scale DSGE model by incorporating endogenously binding collateral constraints.[24] Still, except Canzoneri et al. (2016), the frictions in the financial markets are ignored in the explanations. Therefore, to build a model with more realistic financial structures is a subject for future research.

[24]By contrast, Sims and Wolff (2018) show that multipliers may not vary much across business cycles in a medium-scale DSGE model with non-separable utility function between private and government consumption.

CHAPTER 3

The effects of Negative Interest Rate Policy(NIRP) expectations on the Fiscal Multiplier

3.1. Introduction

The theoretical papers based on the New Keynesian model predicts the above one fiscal multiplier at the zero lower bound(ZLB). Whereas the empirical evidence, for example Miyamoto et al. (2018), well supports this theoretical finding, other empirical papers such as Ramey and Zubairy (2018) and Crafts and Mills (2013) report the below or above but close to one multiplier at the ZLB. I show that by incorporating the possibility of a regime switch from the ZLB to a negative interest rate policy(NIRP), the fiscal multiplier can range from above one to below one depending on the agents' belief about the regime switch.

Several authors suggest possible explanations for a below one fiscal multiplier at the ZLB. For example, Kiley (2016) explains this using the sticky information model instead of the standard sticky-price model. Mertens and Ravn (2014b) show that the multiplier is below unity if a belief shock drives the ZLB. Hills and Nakata (2018) find that introducing the lagged shadow rate into the Taylor rule can reduce the multiplier at the ZLB. Unlike them, I explain the the fiscal multiplier could be smaller or larger than unity at the ZLB depending on the private sector's expectations about the NIRP.

The reason why I focus on the possibility of NIRP is because it is no longer a strict assumption. Instead, several central banks around the world have been implementing NIRP. The ECB introduced negative rates in 2014, and its deposit rate is currently -0.5%. The Bank of Japan went negative in 2016 with -0.1% of the short-term rate. Even in the countries that have not adopted NIRP, such as the U.S. and the UK, the private sector unevenly expects the adoption of NIRP whenever the ZLB constrains the economy and its spell is predicted to last regardless of the central bank's intention for that.

In addition, as recently documented in the literature, for example, Holston et al. (2017) and Del Negro et al. (2019), a permanent decline in the natural rate of interest, especially in advanced economies, seems to constrain their effective lower bounds more frequently, which urges the central banks to adopt NIRP in the future.

I use small-scale Markov-Switching DSGE model to incorporate the monetary policy uncertainty about NIRP. While the effective lower bound of a central bank is set to zero in the ZLB regime, it is set below zero in the NIRP regime. I assume that the agents in the economy understand the effective lower bound in each regime. The private sectors in the model assign a positive probability of regime switch from ZLB to NIRP and vice versa, which reflects the uncertainty about the policy. Independent of the private sector's expectation, the fiscal authority increases the government spending at the ZLB to stimulate subdued demand. The goal of this chapter is to see how much the stimulative effects of an increase of government spending change at the ZLB conditional on the expectation about the transition from ZLB to NIRP.

In my simulation, the economy is hit by negative demand shocks large enough to render the ZLB constraint binding. Given that, I compare the fiscal multiplier in the economy where agents do not expect the NIRP at all with the economy where the private sector assigns some probability to the transition. The same size of government spending is increased in both cases, which is not big enough to lead the economy to exit the ZLB. That is, I focus on the fiscal multiplier at the ZLB irrespective of whether a NIRP is expected. As emphasized by the literature such as Braun et al. (2013), Fernández-Villaverde et al. (2015) and Lindé and Trabandt (2018), the solution method can also affect the size of the fiscal multiplier, especially around the ZLB. When the model is solved based on linearization, it rules out local dynamics obtained in the true nonlinear model at the ZLB. This leads the multiplier at the ZLB to be above one or more significant. By taking this point seriously, I solve the model fully nonlinearly to calculate the multiplier.

Under a baseline parameterization of the model intended to mimic Fernández-Villaverde et al. (2015), the output multiplier at the ZLB is 1.5 with no NIRP expectation, but falls nonlinearly as the private sector puts more possibility of the transition to NIRP. When the private sector expects the economy to stay in the ZLB regime for ten quarters, on average, the multiplier decreases by about 13.9 percent(from 1.51 to 1.30), and for 5 quarters, it falls by 10.6 percent(from 1.30 to 1.16), and as the probability increases, the multiplier falls less. When the agents expect the economy to switch to the NIRP regime in two quarters, on average, the fiscal multiplier falls below the unity. What is important is that this result is not derived from the fact that the fiscal multiplier in the NIRP regime is below one. Instead, the multiplier under NIRP without no expectation about the transition to ZLB is still higher than the unity, 1.52. This shows that the belief about the regime switch to NIRP can solely mitigate the size of fiscal multipliers, and those effects are nontrivial.

At the ZLB, the possibility of NIRP in the future raises inflation expectations, which boosts demand by lowering real interest rates. As the economy experiences less severe recessions, the same size of government spending increases stimulates the economy less. It turns out that the stimulative effects from the expectation channel are strong when the agents start assigning the possibility of regime switch at first, and it gets weaker as they firmly believe in the switch. This is why the fiscal multiplier falls nonlinearly as the probability of remaining ZLB declines. By contrast, when the economy is outside the ZLB, the possible NIRP rarely affects the economic dynamics and the multiplier.

I conduct several sensitivity analysis to check the robustness of my results: the probability of remaining in NIRP regime, flat Phillips curve, size of government spending shocks, and the level of ELB. While the extent to which the mechanism affects the fiscal multiplier varies depending on the related assumptions, the main results still survive with different circumstances. I also want to highlight that the mechanism I explained above also can be applied to more general toolkit which provides additional accommodative policies that can be used by the central bank. For example, it can be extended to the case of quantitative easing, too.

The rest of this chapter is organized as follows. I review the related literature in section 3.2 and present the model in section 3.3. In section 3.4, I show quantitative findings and sensitivity analysis is conducted in section 3.5. Section 3.6 concludes.

3.2. Literature Review

My work is related to the theoretical literature which studies the fiscal multiplier at the ZLB. One strand shows that the multiplier at the ZLB is above one. Among them are Christiano et al. (2011), Woodford (2011), Eggertsson (2011) and Leeper et al. (2017). The empirical evidence well supports this theoretical finding, for example, Miyamoto et al. (2018).

On the contrary, several papers show that the multiplier is below one even at the ZLB. Empirically, Ramey and Zubairy (2018) and Crafts and Mills (2013) reported the below or above but close to one multiplier at the ZLB. Using UK data, Glocker et al. (2019) find no specific effect of the ZLB on the size of the multiplier, which varies conditional on the business cycle. Kiley (2016), Hills and Nakata (2018) and Mertens and Ravn (2014b) explain this finding theoretically with different mechanisms.

Kiley (2016) shows that, under the sticky information model, the fiscal multiplier is less than one, positive productivity shocks raise output, and greater price flexibility moves the economy toward the neoclassical benchmark, which is hard to explain under the sticky-price model. Hills and Nakata (2018) find that the presence of the lagged shadow policy rate—a hypothetical policy rate that would prevail were it not for the ZLB constraint— in the interest rate feedback rule reduces the government spending multiplier nontrivially at the ZLB. With policy inertia, the central bank speeds up the return of the policy rate after the recession ends, responding to the increase in inflation and output due to higher government spending. The faster normalization dampens the expansionary effects during the recession, which results in a low fiscal multiplier. Mertens and Ravn (2014b) show that the increase of government spending becomes less effective at the ZLB if a loss in confidence drives the recession. The reason is that the demand stimulus makes the agents believe that things are much worse than they think.

I show that tagents' expectations about a monetary policy change to a NIRP can reconcile these two arguments. While the fiscal multiplier is above one if the private sector has a low expectations about the NIRP, it falls below one as the agents expect the adoption of NIRP with solid belief. A possible looser monetary policy mitigates the severity of the shocks by stimulating future inflation expectations, and this leads to the lower fiscal multiplier. Once the central bank adopts the NIRP, as the agents do not expect the looser policy in the future any more, the expectation channel is shut down and the fiscal multiplier stays above one for the sever recessions which causes the effective lower bound to bind.

My work is also related to the NIRP literature. Eggertsson et al. (2019) find that the NIRP has contractionary effects on output but point out that it could have a nontrivial positive impact on output if other channels are considered. Brunnermeier and Koby (2018) show that the intended effect of accommodative monetary policy can be reversed even in the positive territory. Based on the model with a monopolistic banking sector, Ulate (2021) finds that the negative interest rates are between 60% and 90% as effective as in positive rates. Sims and Wu (2021a) find that the NIRP becomes less effective as the central bank carries larger balance sheet, and that large cut is required to stimulate the economy. De Groot and Haas (2022) show that NIRP is expansionary through the signaling channel, which means that the central bank signals lower-for-longer policy through the NIRP.

Compared to this literature which focuses on the effects of NIRP itself, I explore the effects of the possible NIRP on the fiscal multiplier. I show that the effects are nontrivial depending on the agents' expectations about regime switch to NIRP.

3.3. Model

The model is based on the standard New Keynesian(NK) model. The economy consists of 3 sectors: household, firms and government. Households consume and save final goods and supply labor to intermediate firms. The intermediate goods are produced by hiring labor from households in monopolistically competitive markets. Because of monopolistic power, each intermediate good firm changes its own price with some rigidity following a Calvo rule. The final good producer assembles the intermediate goods. A government sets the one-period nominal interest rate and taxes while consuming final goods. One deviation from the standard NK is that I give agents in the model rational expectations about the probability of regime switch between ZLB and NIRP. Therefore, the agents take this possibility into account when they make their optimal decisions in each period of time.

3.3.1. Household. A representative household maximizes the following lifetime utility function at period 0

$$E_0\Sigma_{t=0}^{\infty}\left(\Pi_{i=0}^{t}\beta_i\right)\left\{log\ c_t-\psi\frac{l_t^{1+\varphi}}{1+\varphi}\right\} \tag{3.1}$$

The discount factor β_t whose mean is β evolves following a law of motion

$$\beta_t=\beta^{1-\rho_b}\beta_{t-1}^{\rho_b}exp(\sigma_b\epsilon_{b,t}) \tag{3.2}$$

where $\beta_0=\beta$, $\epsilon_{b,t}\sim N(0,1)$. ρ_b and σ_b are persistence and standard deviation of the process. φ determines the curvature of the disutility of labor and ψ is the normalization parameter.

The household consumes the final goods c_t and saves using nominal government bonds b_t whose net supply is zero. They pay a nominal gross interest rate of R_t. The household also supplies labor l_t at the real wage of w_t. Then, the budget constraint is given as

$$c_t + \frac{b_{t+1}}{p_t} = w_t l_t + R_{t-1}\frac{b_t}{p_t} + T_t + F_t \tag{3.3}$$

where p_t is a price of the final good, T_t and F_t are a lump-sum transfer and the profits of the firms. The first-order conditions are

$$\frac{1}{c_t} = E_t\left\{\beta_{t+1}\frac{1}{c_{t+1}}\frac{R_t}{\Pi_{t+1}}\right\} \tag{3.4}$$

$$w_t = \psi l_t^{\varphi} c_t \tag{3.5}$$

where $\Pi_t = \frac{p_t}{p_{t-1}}$ is a gross inflation rate.

3.3.2. The final good firm. The final firm assembles the intermediate goods y_{it} to produce the final good y_t using the following technology

$$y_t = \left(\int_0^1 y_{it}^{\frac{\epsilon-1}{\epsilon}} di\right)^{\frac{\epsilon}{\epsilon-1}} \tag{3.6}$$

where ϵ is the elasticity of substitution. Since it is in the competitive market, it takes the final good price p_t and all intermediate goods prices p_{it} as given. Then, its profit maximization problem gives the demand for an each intermediate good

$$y_{it} = \left(\frac{p_{it}}{p_t}\right)^{-\epsilon} y_t \tag{3.7}$$

for all $i \in [0, 1]$ and the expression of aggregate price index

$$p_t = \left(\int_0^1 p_{it}^{1-\epsilon} di\right)^{\frac{1}{1-\epsilon}}. \tag{3.8}$$

3.3.3. Intermediate good firms. Each intermediate firm produces a differentiated good, but they all use an identical technology $y_{it} = l_{it}$, where l_{it} is the amount of labor hired. Following Calvo (1983), in each period, a fraction of $1 - \theta$ of intermediate good firms reoptimizes their prices to $p_t^* = p_{it}$, while a fraction θ keeps their prices unchanged. This environment implies that the aggregate price dynamics are described by the equation

$$1 = \theta \Pi_t^{\epsilon-1} + (1-\theta)(\Pi_t^*)^{1-\epsilon} \tag{3.9}$$

where $\Pi_t^* = p_t^*/p_t$. Its cost minimization problem gives $mc_t = w_t$, where mc_t is the real marginal cost. Then, the profit maximization problem of each intermediate good firm is to choose the same p_t^*

$$\max \Sigma_{k=0}^{\infty} \left(\Pi_{s=0}^{k} \beta_{t+s}\right) \frac{c_{t+k}}{c_t} \left[\frac{p_t^*}{p_{t+k}} y_{i,t+k} - mc_{t+k} y_{i,t+k} \right]$$
$$s.t \; y_{it} = \left(\frac{p_t^*}{p_t}\right)^{-\epsilon} y_t$$

, which satisfies the following equations

$$\epsilon x_{1,t} = (\epsilon - 1) x_{2,t} \tag{3.10}$$

$$x_{1,t} = \frac{w_t}{c_t} y_t + \theta E_t \beta_{t+1} \Pi_{t+1}^{\epsilon} x_{1,t+1} \tag{3.11}$$

$$x_{2,t} = \frac{\Pi_t^*}{c_t} y_t + \theta E_t \beta_{t+1} \Pi_{t+1}^{\epsilon-1} \frac{\Pi_t^*}{\Pi_{t+1}^*} x_{2,t+1} \tag{3.12}$$

where $x_{1,t}$ and $x_{2,t}$ are auxiliary variables.

3.3.4. Government. The monetary authority sets the nominal interest rate according to $R_t = \max\{elb(s_t), R_t\}$ where

$$R_t = R\left(\frac{\Pi_t}{\Pi}\right)^{\phi_\pi}. \tag{3.13}$$

Π is the target level of inflation and $R = \frac{\Pi}{\beta}$ is the target nominal gross return of bonds. I do not consider an inertial term in monetary policy rule intentionally. Hills and Nakata (2018) documented that including the inertia terms can explain why the fiscal multiplier at ZLB can be low. Thus, I show that my results do not depend on the inertial term.[1] $elb(s_t)$

[1] In addition, Fernández-Villaverde et al. (2015) do not include the inertial term, either, for the computational efficiency. Since I am following their model and calibration for comparison, I follow suit.

represents an effective lower bound of the monetary policy and it is in one of the two regimes depending on the regime state, s_t. Whereas $elb(1) = 1$ whenever $s_t = 1$, $elb(2) = 0.995$ if $s_t = 2$: that is, regime1 is the ZLB regime and regime2 is the NIRP regime. For the baseline case, I assume the ELB in NIRP regime is -2% in an annualized term and the agents understand the effective lower bounds in each regime. Once the economy is stuck at the ZLB, the agents anticipate the adoption of NIRP from the central bank. The regime index, s_t, evolves according to the transition matrix

$$\begin{pmatrix} p_{11} & 1-p_{11} \\ 1-p_{22} & p_{22} \end{pmatrix}$$

which means that switching from ZLB to NIRP occurs with probability of $1 - p_{11}$, and the from NIRP to ZLB with $1 - p_{22}$. p_{11} or p_{22} could change depending on the state of the economy, but for simplicity, I assume they are fixed. In that sense, my analysis is relatively focused on the short term dynamics where the agents update their beliefs slowly. This chapter aims to explore how the fiscal multiplier is affected as the agent's expectation of switching from ZLB to NIRP, $1 - p_{11}$, changes.

The government spending, $g_t = s_{g,t} y_t$, is financed by lump-sum taxes, T_t, with

$$s_{g,t} = s_g^{1-\rho_g} s_{g,t-1}^{\rho_g} exp(\sigma_g \epsilon_{g,t}) \tag{3.14}$$

where $\epsilon_{g,t} \sim N(0,1)$. $s_{g,t}$ is a fraction of government spending relative to output and ρ_g and σ_g are persistence and standard deviation of the process. I assume $b_t = 0$ throughout the paper because of Ricardian equivalence.

3.3.5. Aggregation and Equilibrium. While a resource constraint of the model is $y_t = c_t + g_t$, aggregate production function is $y_t = \frac{l_t}{v_t}$ where $v_t = \int_0^1 \left(\frac{p_{it}}{p_t}\right)^{-\epsilon} di$ is a measure of price dispersion across firms. Using Calvo pricing property, I can rewrite the dispersion equation as $v_t = \theta \Pi_t^{\epsilon} v_{t-1} + (1-\theta)(\Pi_t^*)^{-\epsilon}$. The equilibrium of this model is the sequence of $\{y_t, c_t, l_t, x_{1,t}, x_{2,t}, w_t, \Pi_t, \Pi_t^*, v_t, R_t, Z_t, \beta_t, g_t, s_{g,t}\}_{t=0}^{\infty}$ which satisfies the following equations given the initial states of the economy.

$$\frac{1}{c_t} = E_t\left[\beta_{t+1}\frac{1}{c_{t+1}}\frac{R_t}{\Pi_{t+1}}\right] \tag{3.15}$$

$$\psi l_t^{\varphi} c_t = w_t \tag{3.16}$$

$$\epsilon x_{1,t} = (\epsilon - 1)x_{2,t} \tag{3.17}$$

$$x_{1,t} = \frac{w_t}{c_t}y_t + \theta E_t[\beta_{t+1}\Pi_{t+1}^{\epsilon}x_{1,t+1}] \tag{3.18}$$

$$x_{2,t} = \Pi_t^*\left(\frac{y_t}{c_t} + \theta E_t\left[\beta_{t+1}\frac{\Pi_{t+1}^{\epsilon-1}}{\Pi_{t+1}^*}x_{2,t+1}\right]\right) \tag{3.19}$$

$$R_t = max\left(elb(s(t)), R\left(\frac{\Pi_t}{\Pi}\right)^{\phi_\pi}\right) \tag{3.20}$$

$$g_t = s_{g,t}y_t \tag{3.21}$$

$$1 = \theta\Pi_t^{\epsilon-1} + (1-\theta)(\Pi_t^*)^{1-\epsilon} \tag{3.22}$$

$$v_t = \theta\Pi_t^{\epsilon}v_{t-1} + (1 - theta)(\Pi_t^*)^{-\epsilon} \tag{3.23}$$

$$y_t = c_t + g_t \tag{3.24}$$

$$y_t = \frac{l_t}{v_t} \tag{3.25}$$

$$\beta_t = \beta^{1-\rho_b}\beta_{t-1}^{\rho_b}exp(\sigma_b\epsilon_{b,t}) \tag{3.26}$$

$$s_{g,t} = s_g^{1-\rho_g}s_{g,t-1}^{\rho_g}exp(\sigma_g\epsilon_{g,t}) \tag{3.27}$$

3.3.6. Calibration and Solution method. I calibrate the model following Fernández-Villaverde et al. (2015). $\beta = 0.994$ is set to match an annual real interest rate of 2.5 percent, $\varphi = 1$ for a Frishch elasticity of 1, and $\psi = 1$, which is a normalization of the hours worked. $\epsilon = 6$ implies 20 percent of an average markup, and $\theta = 0.75$ means an average price duration of four quarters. The parameters in the monetary policy are standard: $\phi_\pi = 1.5$, $\phi_y = 0.25$ and $\Pi = 1.005$. In the fiscal policy side, I assume the fraction of government spending out of output is 20 percent, on average, so set $s_g = 0.2$. For the preference shocks, I set $\rho_b = 0.8$ and $\sigma_b = 0.0025$. The parameters for the government spending shocks, $\rho_g = 0.8$ and $\sigma_g = 0.0025$ are used.

TABLE 3.1. Baseline calibration

	Parameters	Values
β	discount facot	0.994
φ	inverse of Frisch elasticity	1
ψ	normalization parameter	1
ϵ	elasticity of substitution	6
θ	fraction of firms not changing price	0.75
ϕ_π	response to inflation in MP	1.5
ϕ_y	response to output in MP	0.25
Π	target inflation	1.005
s_g	fraction of gov.spending in SS	0.2
ρ_b	persistence of discount factor	0.8
ρ_g	persistence of gov. spending	0.8
σ_b	standard deviation of discount factor	0.0025
σ_g	standard deviation of gov. spending	0.0025

Following Richter et al. (2014), I solve the model globally with time iteration and linear interpolation. Expectations are evaluated with Rouwenhorst (1995), which Kopecky and Suen (2010) show that it outperforms other methods for approximating autoregressive processes. A detailed description of the solution method is provided in Appendix C.1.

Throughout the paper, I report the cumulative fiscal multiplier for output computed as

$$M(k) = \frac{\sum_{s=1}^{k} \frac{\Delta y_{t+s-1}}{\Pi_{j=1}^{s} r_{t+j-1}}}{\sum_{s=1}^{k} \frac{\Delta g_{t+s-1}}{\Pi_{j=1}^{s} r_{t+j-1}}} \tag{3.28}$$

where Δ denotes the level changes between simulated paths with and without a government spending increase, and $r_t = E_t\left[\frac{R_t}{\Pi_{t+1}}\right]$ is the real interest rate. Even though this is different from what Fernández-Villaverde et al. (2015) reported[2], the fiscal multipliers at impact are the same for both definitions.

[2]They reporeted $\frac{y_{g,t}-y_1}{g_{g,1}-g_1}$, where y_1 and g_1 are the unconditional means of output and government spending, and $y_{g,t}$ is the simulated path of output with increased government spending.

3.4. Results

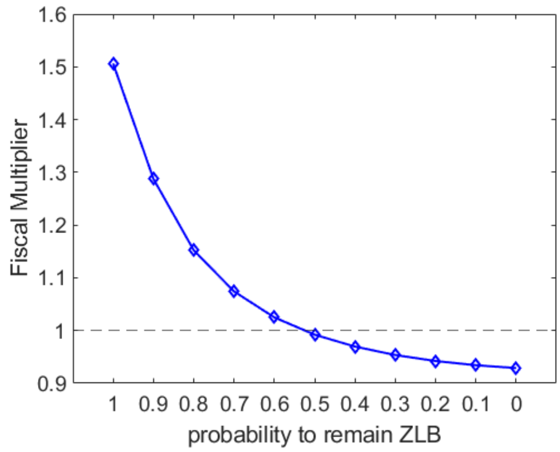
This section reports the fiscal multiplier at the ZLB with the regime switch. To compute the multiplier at the ZLB, I proceed as follows:

1. The economy is at the unconditional mean of states except that the discount factor is set 3.6 percent above its unconditional mean(at 1.03 instead of its mean 0.994). This pushes the economy into the ZLB in the ZLB regime and into the ELB in the NIRP regime, respectively, for 4 consecutive quarters, on average, without any additional shocks.
2. Given the initial state, I simulate the economy with randomly drawn preference and government spending shocks and store the path.
3. With the same state and shock series, except that the fraction of government spending relative to output increases by 1 percent at impact, I simulate the economy again and store the resulting path.
4. I compute the fiscal multiplier based on the formula (3.28).

3.4.1. Fiscal multiplier at the ZLB. Figure 3.1 shows how the on-impact fiscal multipliers change conditional on the probability of remaining at the ZLB, p_{11}, when the economy is in the ZLB regime initially. In the baseline scenario, I assume that once the monetary regime switches to NIRP regime, the economy stays there forever, that is $p_{22} = 1$. Later, I study how the multipliers change as p_{22} varies.

Note, first, that the multiplier without no expectation of regime switch, that is when $p_{11} = 1$, is about 1.5. This figure is lower than what Fernández-Villaverde et al. (2015) reported, 1.76. This is because the model does not include 2 exogenous shocks, productivity shocks and monetary policy shocks, compared to them. Their model tends to visit ZLB constraints more frequently with additional exogenous shocks, which lowers the unconditional mean of output and inflation. This would make their multiplier higher than what reported here.

FIGURE 3.1. Fiscal multiplier on impact conditional on the probability of remaining at ZLB



Note: The blue line shows the on-impact fiscal multipliers at the ZLB given the agents' beliefs of regime switch to NIRP in different levels. x-axis represents the probability of remaining at ZLB, p_{11}.

As the agents assign more probability of switching to the NIRP regime, the fiscal multiplier declines. What is interesting is that the fiscal multiplier falls nonlinearly along the probability. That is, when the private sector assigns initially small probability to regime switch, that is when $p_{11} = 0.9$, the multiplier decreases by about 13.9 percent(from 1.5 to 1.30) compared to the no expectation case. In case of $p_{11} = 0.8$, it falls by 10.6 percent(from 1.30 to 1.16) relative to the case of $p_{11} = 0.9$. In the same manner, as the probability increases, the multiplier falls less. The fiscal multiplier lies below the unity from $p_{11} = 0.5$, when the agents expect the ZLB regime to last for about 2 quarters, on average.

Another extreme case is when $p_{11} = 0$. If it is believed that the monetary policy regime switches to NIRP without uncertainty, while the actual regime is still the ZLB regime, the fiscal multiplier falls all the way down to 0.93 even though the economy is still in the ZLB regime.

One thing to note is that the multiplier in the NIRP regime is about 1.52, which is very close to that under the ZLB regime with $p_{11} = 1$[3]. This implies that the negative effective lower bound scarcely affects the fiscal multiplier given the same series of shocks across the simulations. I want to highlight that the fiscal multipliers in the ZLB regime with positive p_{11} are below than those under pure ZLB or NIRP regime. This shows that the belief about the regime switch to NIRP can solely lower the size of fiscal multipliers. To understand these results, it is useful to examine how the government spending shock affects the dynamics of the economy with and without the expectation of the regime switch.

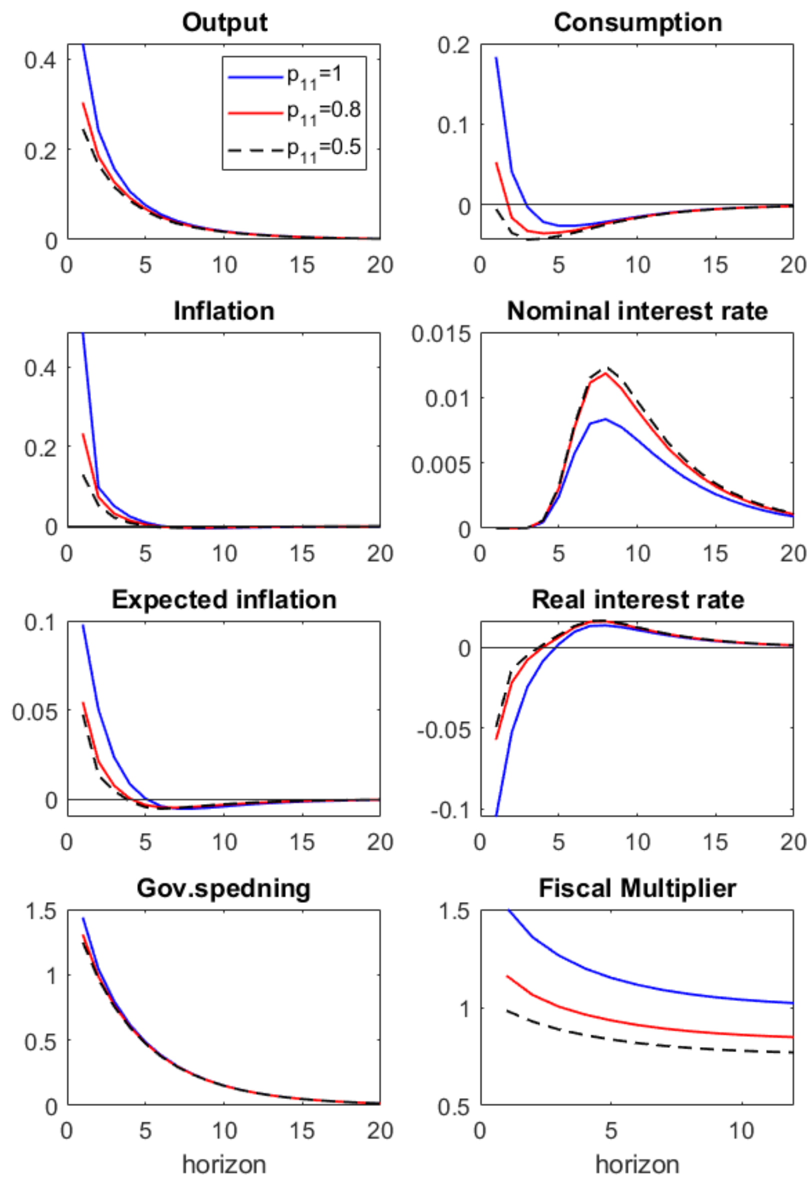
Figure 3.2 demonstrates the impulse responses of variables in the model to the increase of government shock when the economy is at the ZLB after large discount factor shocks hit the economy with various levels of p_{11}. Therefore, we can think of this figure as the marginal effects of the government spending shocks on the economy. In each panel, the solid blue line is the case of $p_{11} = 1$, the red line $p_{11} = 0.8$ and the dashed black line $p_{11} = 0.5$.

When the private sector does not expect the NIRP at all, that is the case of $p_{11} = 1$, the increase of government shock raises the demand for the final good, which in turn increases output, inflation and expected inflation. Given the nominal interest rate stuck at the ZLB, the real interest rate falls on impact and returns to the unconditional mean over the horizon. Since the consumption today is determined by a stream of future expected real interest rates, the consumption increases on impact, which causes output to rise further in addition to the increase of government spending. Therefore, the fiscal multiplier on impact is above the unity, 1.51.

Even after the economy exits the ZLB as the shock dissipates, the government spending still remains high because it follows its law of motion. Outside the ZLB, the central bank raises the nominal interest rates following the monetary policy Z_t responding to the resulting

[3]Of course, this is due to the assumption that the demand shocks which drive the economy into the ZLB also render the ELB in the NIRP regime remain constrained for the same number of quarters, on average.

FIGURE 3.2. GIRFs at the ZLB with different probabilities of switching to NIRP



Note: The blue line corresponds to the case of $p_{11} = 1$, the red line is for $p_{11} = 0.8$ and the black dashed line represents the case of $p_{11} = 0.5$. Inflation, nominal interest rate, expected inflation and real interest rate are expressed in terms of the annualized percentage points. The remaining variables except for fiscal multiplier are expressed as the percentage changes.

increase in inflation and output. Accordingly, the real interest rates rise and the consumption falls, which leads to a further decrease in the fiscal multiplier.

In the case of a red line, when $p_{11} = 0.8$, since the agents expect more looser policy in the next period with uncertainty, the level of output and inflation fall less compared to the blue line case when the same series of shocks hit the economy. That is, the expectation of a regime switch makes the recession less severe. Given that, with the increase in government spending, output and inflation do not increase as much as in the case of blue line. While the output and inflation jump up by 0.41 percent and 0.46 percent on impact in the blue line, they rise only by 0.29 percent and 0.22 percent in the red line.

Inflation expectation also exhibits similar responses. As the left panel in the third row demonstrates, the increase in government spending does not generate as high inflation expectations as in the blue line case because inflation is already picked up by regime switch expectation. As a result, the real interest rates fall less, so the increase in consumption is muted, leading to a lower fiscal multiplier. As the shocks wane, the inflation expectation falls below zero. This is because the agents expect the central bank to raise nominal rates outside the ZLB. Since the monetary authority adjusts the policy rate responding to the output as well as the inflation, somewhat aggressive changes of policy rate are expected, which mitigates the inflation expectation more. If we assume no response to output in the monetary policy rule, the inflation expectation would not fall below zero.

Once the economy exits the ZLB, the expectation of a regime switch rarely affects the dynamics because the central bank sets the policy rate using the equation 3.13 in both regimes. Therefore, the normalization of the nominal interest rates after the ZLB is very similar across different p_{11} represented by the right panel in the second row[4]. Nevertheless, we observe that the central bank raises the nominal interest rates further once the economy exits the ZLB when the private sector assigns some probability to NIRP. Since the expectations about NIRP mitigate the severity of recessions, the negative output gap and inflation gap

[4]Since the unit is annualized percentage point, the differences between the lines can be seen very small.

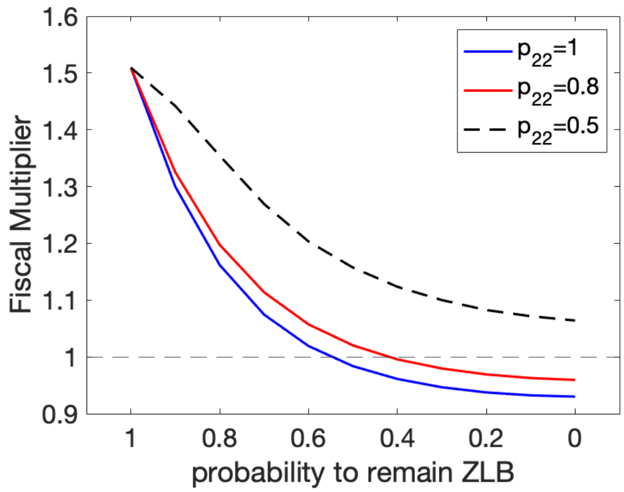
are smaller with the presence of regime switch anticipation both at the ZLB and outside the ZLB. The higher inflation and output path at the ZLB result in the larger adjustment of the policy rate outside the ZLB.

The black dashed lines in all panels represent the case of $p_{11} = 0.5$. As the agents assign more probability to switch to the NIRP regime, the stronger expectation alleviates the effects of the negative shocks further and the fiscal multiplier falls more than the red line case. However, the effects of the stronger belief are marginal in the sense that the difference between the red line and the black dashed line is much smaller than that between the blue line and the red line. This observation explains the nonlinear decrease of the fiscal multiplier in Figure A.8.

3.4.2. Fiscal multiplier outside the ZLB. Lastly, I calculate the fiscal multiplier outside the ZLB. To that end, I assume all state variables are in their unconditional mean and only government spending shocks hit the economy by the same amount as in the previous simulations in the initial period. The fiscal multiplier in this case is about 0.53 regardless of the level of p_{11}, which is comparable to what Fernández-Villaverde et al. (2015) reported. This result shows that the presence of a possible regime switch rarely affects the possibility of binding ZLB in the model, which also could affect the size of the multiplier at the ZLB. This suggests that the change of fiscal multipliers because of regime switch arises mainly due to the expectation channel mentioned above. I present the GIRFs outside the ZLB in Appendix C.3. As one can observe, no significant differences are detected across lines in the panels[5].

[5]One may note that inflation and inflation expectation decrease after the increase of government spending, which looks counterintuitive. The reason is because I assume somewhat strong responses to output gap in the monetary policy rule. If I use lower ϕ_y, those would rise, also.

FIGURE 3.3. Fiscal Multiplier on impact at the ZLB conditional on different p_{22}



Note: The left panel plots the on impact fiscal multipliers at the ZLB given the agents' beliefs of regime switch to NIRP in different levels conditioning on the different level of probability of remaining in the NIRP regime. The blue line is the baseline case where p_{22} is assumed to be 1. The red line and the black dashed line correspond to the case of $p_{22} = 0.8$ and $p_{22} = 0.8$, respectively.

3.5. Sensitivity Analysis

This section performs sensitivity analysis on government spending multipliers at the ZLB along four dimensions: 1) probability of remaining in the NIRP regime, p_{22}; 2) flat Phillips curve; 3) size of government spending shocks; 4) level of effective lower bound.

3.5.1. Probability of remaining in NIRP regime. In section 3.4, I assumed that once the economy switches to the NIRP regime, it stays there forever. In this subsection, I relax that assumption and study how different level of p_{22} alters the baseline results. That is, I compare the fiscal multipliers conditional on different p_{11} given that p_{22} is set to 1, 0.9 and 0.5, respectively.

Figure(3.3) shows the comparisons. The blue line is the baseline case, while the red line and dashed black line represent the case of $p_{22} = 0.9$ and $p_{22} = 0.5$. In case that the agents do not anticipate regime switch to NIRP at all, the fiscal multipliers are almost identical regardless of the level of p_{22}. As the agents assign the probability of returning to the ZLB regime after switching to the NIRP regime, the fiscal multipliers at each p_{11} increase. While the multiplier falls below the unity around $p_{11} = 0.5$ in the blue line, it is around 0.4 in the case of the red line. Especially when the private sectors expect the economy to return to the ZLB regime relatively soon, the multipliers do not go below one.

The reason is that lower p_{22} mitigates the stimulative effects of possible switching to the NIRP regime because the agents anticipate that the economy will return to the ZLB regime in the future. Since the fiscal multiplier is higher when the economy is under more severe recessions, the fiscal multipliers with lower p_{22} lie above those with higher p_{22}.

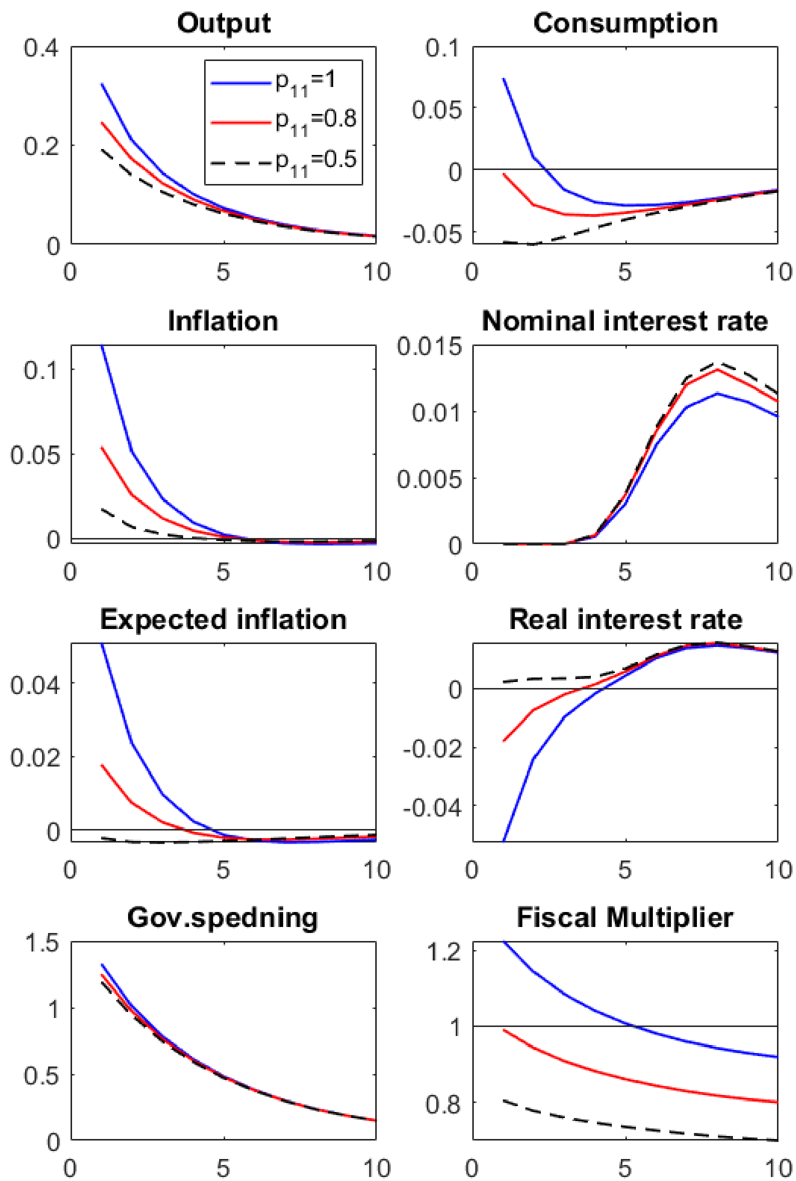
3.5.2. Flat Phillips curve. The recent empirical evidence suggests that the Phillips curve gets flatter[6]. In my baseline parameterization, the slope of the linearized Phillips curve is about 0.08, which is steeper than the data suggests. Thus, I set the parameters such that the slope is close to 0.02. One implication of the flat Phillips curve is that inflation is mainly determined by inflation expectations, while current economy states seldom affect inflation during this period. Since the flat Phillips curve originates from a stickier price assumption, the responses of inflation and output are mitigated relative to the baseline parameterization.

Figure (3.4) demonstrates this. With the same simulation as in Section 3.4 except for the slope of the Phillips curve, what is noticeable is the muted responses of inflation. In Figure (3.2), the inflation in case of $p_{11} = 1$ jumps up above to 0.6 percent on impact, whereas it only rises by about 0.1 percent. A small change in inflation is interpreted as a less increase in output as the first panel of the first row shows. Therefore, the fiscal multiplier is smaller than the baseline case at impact.

In the case of $p_{11} = 0.8$, lower inflation and expected inflation result in a less fall in real interest rates. In the baseline case, it falls by about 0.1 percent, whereas with a flat Phillips

[6]See, for example, Hazell et al. (2020) and Stock and Watson (2020)

FIGURE 3.4. GIRFs at the ZLB with flat Phillips curve



Note: The blue line corresponds to the case of $p_{11} = 1$, the red line is for $p_{11} = 0.8$ and the black dashed line represents the case of $p_{11} = 0.5$. Inflation, nominal interest rate, expected inflation and real interest rate are expressed in terms of the annualized percentage points. The remaining variables except for fiscal multiplier are expressed as the percentage changes.

curve, it only drops by about 0.02 percent. Because of that, the consumption decrease rather than increases on impact, and the fiscal multiplier falls right below the unity even at impact.

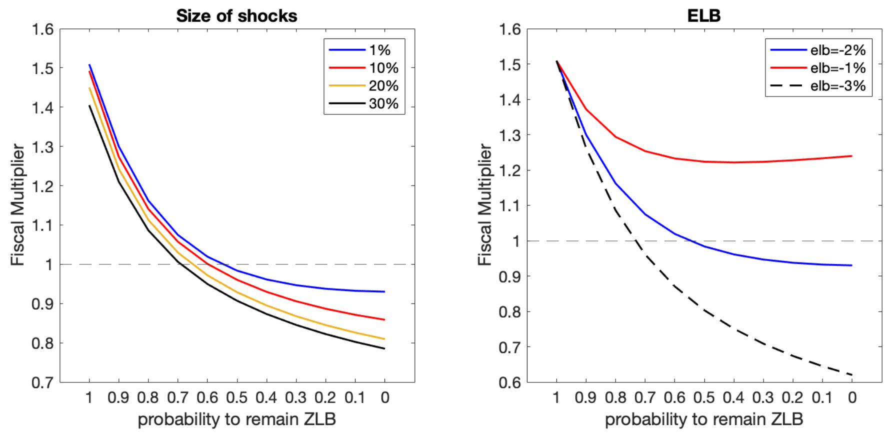
To sum up, with the flat Phillips curve, the fiscal multiplier falls because of smaller responses of inflation and output, and this leads to the below one multiplier even at impact with some probability of switching to the NIRP regime otherwise would be larger than one. Outside the ZLB, though, the slope of Phillips curve rarely affects the size of fiscal multiplier. The multiplier from the flat Phillips curve is about 0.52, which is almost identical to that from the baseline parameterization, 0.53.

3.5.3. Size of government spending shocks. Since the model is solved nonlinearly, the size of the government spending shocks as well as the initial state of the economy determine the size of the fiscal multiplier. In this subsection, I simulate the model again with different sizes of government spending shocks: a fraction of government spending relative to output rises 1%, 10%, 20% and 30%, respectively. The left panel of figure (3.5) shows the result. Following Fernández-Villaverde et al. (2015), I interpret the 1% case as the marginal multiplier and the remaining cases as the indicator of average multipliers.

The fiscal multipliers are large when the size of shocks are small and they decrease as the size of shocks gets bigger. Another observation is that across all the region of high p_{11}, the difference between the marginal and the average multipliers is small. Nevertheless, the average multiplier falls further when the probability is lower. For example, whereas the multiplier is about 1.5 when the fraction increases by 1% under $p_{11} = 1$, it is about 1.4 in the case of 30% shocks. Under $p_{11} = 0$, the multiplier falls from 0.93 to 0.78 as the shocks increase such that the fraction moves from 1% to 30%.

This suggests that the additional government spending is not as effective as the earlier spending if agents strongly believe the regime switch. All of this implies that the larger government spending advances the threshold of probability to remain at the ZLB, which causes below one fiscal multiplier.

FIGURE 3.5. Fiscal Multiplier conditional on the size of government spending and ELB



Note: The left panel shows on impact fiscal multipliers in different size of government shocks. The blue line is the baseline case where the ratio of government spending to output rises by 1%. The redline, yellow line, and black line correspond to the 10%, 20% and 30%, respectively. The left panel displays on impact multipliers in different ELBs. The blue line is the baseline case of -2% in annualized rate. The redline and black dashed line correspond to the case of -1% and -3% in annualized term, respectively.

3.5.4. Level of ELB. Next, I study the effect of ELB on my results. The right panel of Figure (3.5) shows how the multiplier changes conditional on the level of ELB. The blue line is the baseline case where the ELB is set to -2%. The red line represents the case of -1%, and the dashed black line -3% as the ELB, respectively. I repeat the same simulation to calculate the multipliers.

With the ELB of -1%, the fiscal multipliers do not fall as much as the baseline case. With the higher ELB, the central bank raises the nominal interest rates slower so that the inflation expectation increases more, which results in lower real interest rates. Therefore, the consumption and output are stimulated more compared to the baseline case. Even when the agents expect the regime switch to NIRP without uncertainty, the fiscal multiplier is quite above one. On the contrary, when the ELB is lowered further, the opposite mechanism works so that the fiscal multipliers decline. Hence, what the agents think of as the ELB is significant in determining the size of the fiscal multiplier in the model specification.

3.6. Conclusion

In this chapter, I investigate the effect of a possible monetary policy regime switch from ZLB to NIRP on the fiscal multiplier at the ZLB. I show that even with small expectation about the regime switch causes a nontrivial drop in the fiscal multiplier and it falls below unity beyond a certain level of p_{11}.

While my results are robust to several sensitivity analysis, still it has several limitations. First, my results rely on the rational expectations assumption. Instead, if the agents follow non rational expectations, such as bounded rationality or adaptive expectation, the possible regime switch effects would be muted. Second, I am assuming fixed probabilities as the regime switch parameter, which implies that the agents do not correct their belief. By relaxing this assumption, I can adopt the endogenous regime switching model like Davig et al. (2006). While this could generate richer dynamics, the results would not be different qualitatively. Third, I introduce NIRP in the model without financial sector so that one might argue that I overlook the cost of NIRP. I advocate my approach in two aspects. During the debate on the cost and benefit of NIRP, many authors find that the benefit of NIRP outweighs the cost. Ulate (2021) shows that monetary policy in negative territory is 60 to 90 percent as effective as in positive territory using DSGE model with financial sector[7]. Albertini et al. (2021), Bottero et al. (2021) and Lopez et al. (2020) among many others demonstrate that negative rates do not seem to adversely affect the bank profitability. In addition, many recent theoretical papers which analyze the effect of NIRP also take the same approach as mine. Among them are Andrade et al. (2021). Therefore, one can think of my results as the upper bound of possible outcomes obtained from my model specification.

[7]Eggertsson and Singh (2019) and Sims and Wu (2021b) find that NIRP is costly.

My finding has some policy implications. To make government spending in severe recessions most effective, the central bank needs to close the possibility of NIRP clearly. This is what the Fed did in May, 2020. By saying that the fed is not considering NIRP explicitly, the Fed chair publicly ruled out the NIRP in its toolkit to use. Even though there would be several reasons why the Fed publicly announced this, my finding suggests one possible explanation of that strategy. My result can be interpreted more generally in the sense that it is not about ZLB vs NIRP. Rather, it is the discrepancy of effective lower bound(ELB) between the private sector and the central bank. Therefore, as far as the ELB that the agents believe is lower than what the central bank thinks, the effectiveness of fiscal stimulus can be alleviated to some degrees. This interpretation suggests that clear communication about the ELB is helpful to exit severe recessions especially when the economy is already in the vicinity of its ELB and is implementing fiscal policy aggressively.

APPENDIX A

Chapter1 Appendix

A.1. Baseline calibration

Table A.1. Baseline calibration

Conventional Parameters		Value	Target/Source
β	Steady state discount rate	0.994	Real interest rate = 2.4% p.a.
σ	Relative risk aversion	1	Log utility
η	Inverse Frisch elasticity	1	Conventional
h	External consumption habit	0.5	Conventional
ϵ	Price elasticity of demand	7.67	Mark-up = 15%
χ	Disutility labor	1.73	DSS labor supply = 1
φ	Rotemberg pricing	667	Slope of NKPC = 0.01
$4log(\Pi)$	Annualized Inflation targe	2%	Inflation target
ϕ_π	MP inflation response	2	depend on window length
ϕ_y	MP output response	0	
ρ_R	Persistence MP rule	0.7	Bianchi et al. (2021)
$100\sigma_\xi$	Std.dev. Preference shock	2.16	Bianchi et al. (2021)
$100\sigma_m$	Std.dev. MP shock	0.42	Bianchi et al. (2021)
ρ_R	Persistence preference shock	0.9	Bianchi et al. (2021)

A.2. Measuring Welfare Costs

Here I show how to compute welfare costs in the spirit of Schmitt-Grohé and Uribe (2007). This method is also used in Sims and Wu (2021a).

Let λ denote the welfare cost of adopting one policy rule instead of the other conditional on a particular state in period t. Let's denote the former rule a(alternative rule) and the latter one r(reference rule). λ is the fraction of regime r's consumption process that the household would be willing to forfeit to be as well off under regime a as under regime r.

With the Equation 1.1, we have

$$V_t^r(\lambda) = ln((1-h)c_t(1+\lambda)) - \chi\frac{H_t^{1+\eta}}{1+\eta} + \beta E_t V_{t+1}^r(\lambda) \tag{A.1}$$

We can rewrite the above equations as follows:

$$V_t^r(\lambda) = \frac{ln(1+\lambda)}{1-\beta} + ln((1-h)c_t) - \chi\frac{H_t^{1+\eta}}{1+\eta} + \beta E_t V_{t+1}^r(0) \tag{A.2}$$

$$= \frac{ln(1+\lambda)}{1-\beta} + V_t^r(0) \tag{A.3}$$

Thus, the social welfare in SSS is expressed as

$$EV_t^r(\lambda) = \frac{ln(1+\lambda)}{1-\beta} + EV_t^r(0) \tag{A.4}$$

We want to find λ such that $EV_t^r(\lambda) = EV_t^a(0)$. That is,

$$\frac{ln(1+\lambda)}{1-\beta} + EV_t^r(0) = EV_t^a(0) \tag{A.5}$$

Solving for λ, we get

$$\lambda = exp((1-\beta)(EV_t^a(0) - EV_t^r(0)))) - 1 \tag{A.6}$$

A.3. Nonlinear Solution Method

Here, I explain how I solve the model. Below are the equilibrium conditions from the baseline model.

$$\lambda_t = (c_t - hc_{t-1})^{-\sigma} \tag{A.7}$$

$$\lambda_t = \beta E_t\left[\lambda_{t+1}\frac{\xi_{t+1}}{\xi_t}\frac{R_t}{\Pi_{t+1}}\right] \tag{A.8}$$

$$\lambda_t w_t = \chi H_t^{\eta} \tag{A.9}$$

$$mc_t = w_t \tag{A.10}$$

$$0 = 1 - \epsilon + \epsilon mc_t - \varphi\left(\frac{\Pi_t}{\Pi} - 1\right)\frac{\Pi_t}{\Pi} + \varphi\beta E_t\left[\frac{\xi_{t+1}}{\xi_t}\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{\Pi_{t+1}}{\Pi_t} - 1\right)\frac{\Pi_{t+1}}{\Pi_t}\frac{y_{t+1}}{y_t}\right] \tag{A.11}$$

$$c_t = y_t\left[1 - \frac{\varphi}{2}\left(\frac{\Pi_t}{\Pi} - 1\right)^2\right] \tag{A.12}$$

$$R_t^n = (R_{t-1}^n)^{\rho_R}\left[R\left(\frac{\hat{\Pi}_t}{\Pi}\right)^{\phi_\pi}\right]^{1-\rho_R} exp(\sigma^m \epsilon_t^m) \tag{A.13}$$

$$R_t = \max\left(1, R_t^n\right) \tag{A.14}$$

$$\hat{\Pi}_t = \alpha\Pi_t + (1-\alpha)\hat{\Pi}_{t-1} \tag{A.15}$$

$$\xi_t = exp(\rho_\xi log(\xi_{t-1}) + \sigma^\xi \epsilon_t^\xi) \tag{A.16}$$

$$y_t = H_t \tag{A.17}$$

$$W_t = \xi_t\left[\frac{(c_t - hc_{t-1})^{1-\sigma}}{1-\sigma} - \chi\frac{H_t^{1+\eta}}{1+\eta}\right] + \beta E_t W_{t+1} \tag{A.18}$$

I use time iteration with piecewise linear interpolation of policy functions as in Richter et al. (2014). Expectations are calculated based on Rouwenhorst (1995), which Kopecky and Suen (2010) show dominates other methods for approximating autoregressive processes. This method is widely used because of its simplicity and efficiency[1].

[1] For the recent application, see Bianchi et al. (2021).

There are 5 state variables in the system : $\xi_t, \epsilon_t^m, c_{t-1}, \hat{\Pi}_{t-1}, R_{t-1}^n$. I choose H_t, Π_t and W_t as policy variables to approximate. This is not the only set that I can start with. But, I find this set is efficient enough to solve the model easily.:

$$H_t = g^1(\xi_t, \epsilon_t^m, c_{t-1}, \hat{\Pi}_{t-1}, R_{t-1}^n) \tag{A.19}$$

$$\Pi_t = g^2(\xi_t, \epsilon_t^m, c_{t-1}, \hat{\Pi}_{t-1}, R_{t-1}^n) \tag{A.20}$$

$$W_t = g^3(\xi_t, \epsilon_t^m, c_{t-1}, \hat{\Pi}_{t-1}, R_{t-1}^n) \tag{A.21}$$

To solve the model, I approximate the unknown policy functions with piecewise linear functions $\tilde{g}^i$ that can be written as:

$$H_t = \tilde{g}^1(\xi_t, \epsilon_t^m, c_{t-1}, \hat{\Pi}_{t-1}, R_{t-1}^n) \tag{A.22}$$

$$\Pi_t = \tilde{g}^2(\xi_t, \epsilon_t^m, c_{t-1}, \hat{\Pi}_{t-1}, R_{t-1}^n) \tag{A.23}$$

$$W_t = \tilde{g}^3(\xi_t, \epsilon_t^m, c_{t-1}, \hat{\Pi}_{t-1}, R_{t-1}^n) \tag{A.24}$$

Then, the time iteration algorithm is implemented as follows:

1. Define a discretized grid for the states.
2. Guess the piecewise linear policy functions $\tilde{g}^1$ $\tilde{g}^2$ $\tilde{g}^3$.
3. Given state vector, solve for time t policy variables:

$$H_t = \tilde{g}^1(\xi_t, \epsilon_t^m, c_{t-1}, \hat{\Pi}_{t-1}, R_{t-1}^n) \tag{A.25}$$

$$\Pi_t = \tilde{g}^2(\xi_t, \epsilon_t^m, c_{t-1}, \hat{\Pi}_{t-1}, R_{t-1}^n) \tag{A.26}$$

$$W_t = \tilde{g}^3(\xi_t, \epsilon_t^m, c_{t-1}, \hat{\Pi}_{t-1}, R_{t-1}^n) \tag{A.27}$$

then, the remaining variables are given as:

$$y_t = H_t \tag{A.28}$$

$$c_t = y_t\left[1 - \frac{\varphi}{2}\left(\frac{\Pi_t}{\Pi} - 1\right)^2\right] \tag{A.29}$$

$$R_t^n = (R_{t-1}^n)^{\rho_R}\left[R\left(\frac{\hat{\Pi}_t}{\Pi}\right)^{\phi_\pi}\right]^{1-\rho_R} exp(\sigma^m \epsilon_t^m) \tag{A.30}$$

$$R_t = \max\left(1, R_t^n\right) \tag{A.31}$$

$$\lambda_t = (c_t - hc_{t-1})^{-\sigma} \tag{A.32}$$

$$w_t = \frac{\chi H_t^\eta}{\lambda_t} \tag{A.33}$$

$$mc_t = w_t \tag{A.34}$$

For each node of future shocks $\xi_{t+1}^i\, \epsilon_{t+1}^{m,i}$, calculate the next period policy variables, c and λ.

$$H_{t+1}^i = \tilde{g}^1(\xi_{t+1}^i, \epsilon_{t+1}^{m,i}, c_t, \hat{\Pi}_t, R_t^n) \tag{A.35}$$

$$\Pi_{t+1}^i = \tilde{g}^2(\xi_{t+1}^i, \epsilon_{t+1}^{m,i}, c_t, \hat{\Pi}_t, R_t^n) \tag{A.36}$$

$$W_{t+1}^i = \tilde{g}^3(\xi_{t+1}^i, \epsilon_{t+1}^{m,i}, c_t, \hat{\Pi}_t, R_t^n) \tag{A.37}$$

$$c_{t+1}^i = y_{t+1}^i\left[1 - \frac{\varphi}{2}\left(\frac{\Pi_{t+1}^i}{\Pi} - 1\right)^2\right] \tag{A.38}$$

$$\lambda_{t+1}^i = (c_{t+1}^i - hc_t)^{-\sigma} \tag{A.39}$$

Next, derive the errors for the Euler Equation, the New Keynesian Phillips curve and Social welfare equation:

$$(A.40) \qquad err_1 = 1 - \beta E_t\left[\frac{\lambda_{t+1}}{\lambda_t}\frac{\xi_{t+1}}{\xi_t}\frac{R_t}{\Pi_{t+1}}\right]$$

$$(A.41) \qquad err_2 = 1 - \epsilon + \epsilon mc_t - \varphi\left(\frac{\Pi_t}{\Pi} - 1\right)\frac{\Pi_t}{\Pi} + \varphi\beta E_t\left[\frac{\xi_{t+1}}{\xi_t}\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{\Pi_{t+1}}{\Pi_t} - 1\right)\frac{\Pi_{t+1}}{\Pi_t}\frac{y_{t+1}}{y_t}\right]$$

$$(A.42) \qquad err_3 = \xi_t\left[\frac{(c_t - hc_{t-1})^{1-\sigma}}{1-\sigma} - \chi\frac{H_t^{1+\eta}}{1+\eta}\right] + \beta E_t W_{t+1} - W_t$$

4. Use Chris Sims's *csolve* to find a root which minimizes the above errors.
5. Repeat step 2-4 until $maxdist < 10^{-5}$, where $maxdist = \max\{|H_t^i - H_t^{i-1}|, |\Pi_t^i - \Pi_t^{i-1}|, |W_t^i - W_t^{i-1}|\}$. When that criterion is satisfied, the algorithm has converged to an approximate nonlinear solution.

A.4. Generalized Impulse Response Functions

I follow Koop et al. (1996) to produce GIRFs. The GIRFs are derived from the average path from repeated model simulations and calculated as follows:

1. Feed the initial state vector into each simulation. A common initial state is a stochastic steady state.
2. Draw random preference shocks and monetary policy shocks $\{\xi_t, \epsilon_t\}_{t=0}^{N}$for each simulation where N is the horizon of simulation. From the initial state vector, simulate the model R times. Thus, we have $R(= 10,000)$ random draw series with N horizon each.
3. Using the same R draws of shock from step 2, replace the preference shock in period one with a size of shock interested in. Then, simulate the model with these alternate sequences of shocks to obtain R equilibrium paths.
4. Average across the R simulations from step 2 and 3 to obtain average paths.
5. The difference between these two series is a GIRF.

When I calculate the government spending multiplier, I modify the step accordingly.

A.5. Nonlinear Equilibrium Conditions with Government Spending Shocks.

This subsection shows the nonlinear equilibrium conditions for the fiscal multiplier.

$$\lambda_t = c_t^{-\sigma} \tag{A.43}$$

$$\lambda_t = \beta E_t\left[\lambda_{t+1}\frac{\xi_{t+1}}{\xi_t}\frac{R_t}{\Pi_{t+1}}\right] \tag{A.44}$$

$$\lambda_t w_t = \chi H_t^{\eta} \tag{A.45}$$

$$mc_t = w_t \tag{A.46}$$

$$0 = 1 - \epsilon + \epsilon mc_t - \varphi\left(\frac{\Pi_t}{\Pi} - 1\right)\frac{\Pi_t}{\Pi} + \varphi\beta E_t\left[\frac{\xi_{t+1}}{\xi_t}\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{\Pi_{t+1}}{\Pi_t} - 1\right)\frac{\Pi_{t+1}}{\Pi_t}\frac{y_{t+1}}{y_t}\right] \tag{A.47}$$

$$c_t = y_t - g_t \tag{A.48}$$

$$R_t^n = R\left(\frac{\hat{\Pi}_t}{\Pi}\right)^{\phi_\pi} \tag{A.49}$$

$$R_t = \max\left(1, R_t^n\right) \tag{A.50}$$

$$\hat{\Pi}_t = \alpha\Pi_t + (1-\alpha)\hat{\Pi}_{t-1} \tag{A.51}$$

$$\xi_t = exp(\rho_\xi log(\xi_{t-1}) + \sigma^\xi \epsilon_t^\xi) \tag{A.52}$$

$$g_t = exp((1-\rho_g)log(g_{ss})\rho_g log(g_{t-1}) + \sigma^g \epsilon_t^g) \tag{A.53}$$

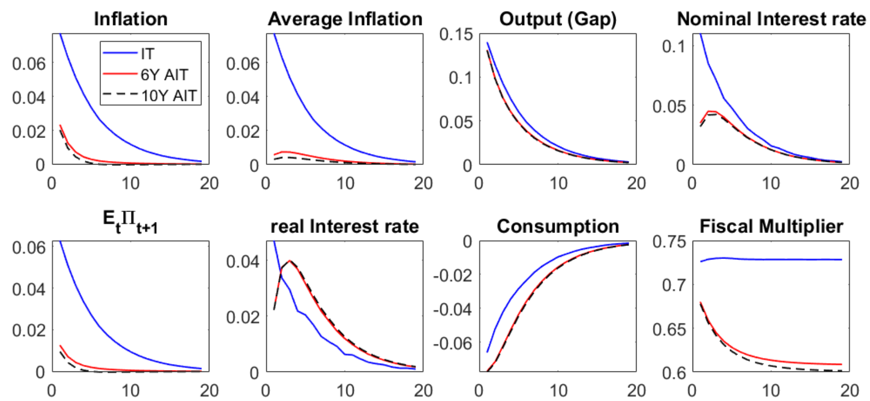
$$y_t = H_t \tag{A.54}$$

I assume no habit and no inertia in the monetary policy rule. Also, the price adjustment costs are not physical menu costs, but are only perceived by firms when they maximize their profit. Hence, the costs are not appeared in the resource constraint. I solve the model nonlinearly as in Appendix A.3.

A.6. GIRFs of fiscal multiplier sensitivity analysis

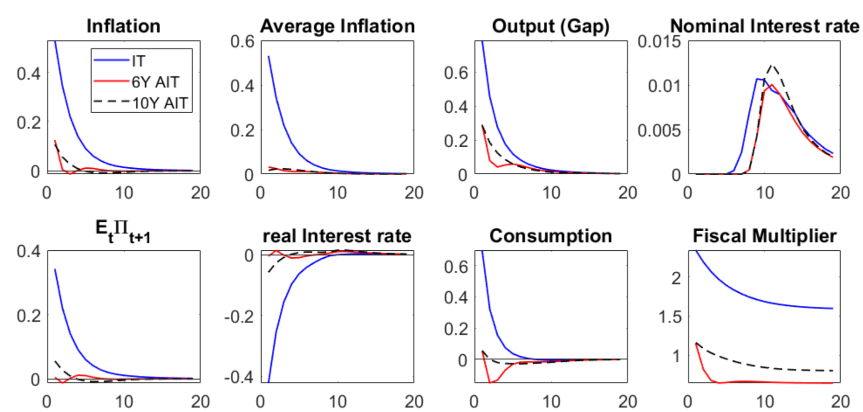
[Steep Phillips curve]

FIGURE A.1. Outside the ZLB



Note: Except for output, consumption and fiscal multiplier, the y-axis is the annualized percentage point difference between a path with and without government spending shocks. Output is the difference between two paths scaled by the SSS values. Fiscal multiplier is the cumulative multiplier computed by equation (3.28).

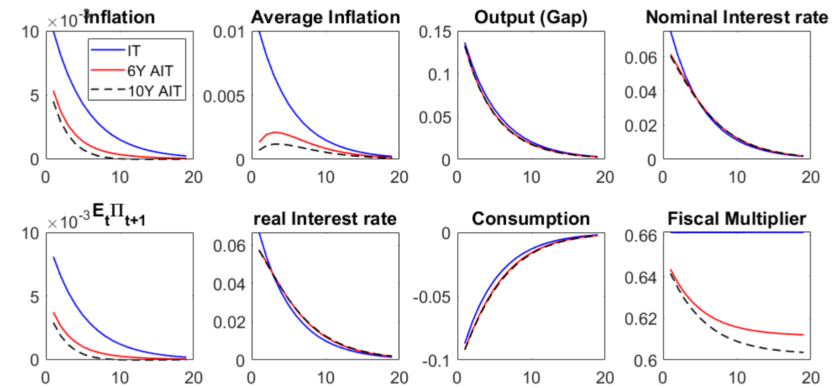
FIGURE A.2. At the ZLB



Note: Except for output, consumption and fiscal multiplier, the y-axis is the annualized percentage point difference between a path with and without government spending shocks. Output is the difference between two paths scaled by the SSS values. Fiscal multiplier is the cumulative multiplier computed by equation (3.28).

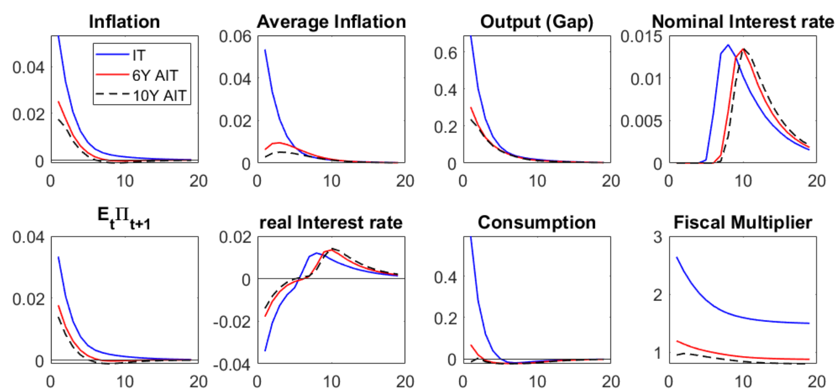
[Response to output gap in monetary policy rule]

FIGURE A.3. Outside the ZLB



Note: Except for output, consumption and fiscal multiplier, the y-axis is the annualized percentage point difference between a path with and without government spending shocks. Output is the difference between two paths scaled by the SSS values. Fiscal multiplier is the cumulative multiplier computed by equation (3.28).

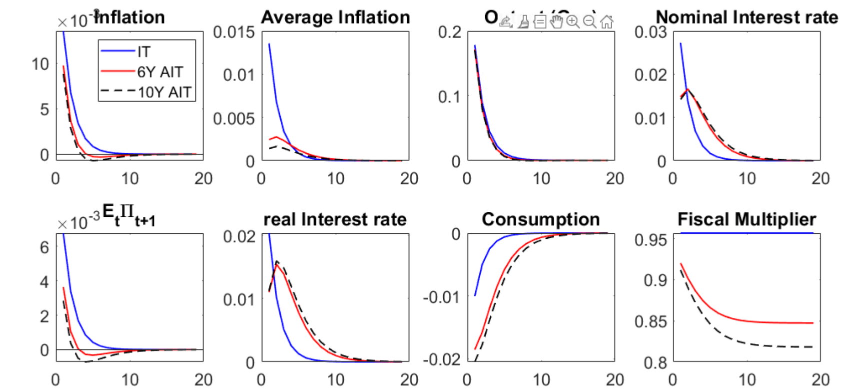
FIGURE A.4. At the ZLB



Note: Except for output, consumption and fiscal multiplier, the y-axis is the annualized percentage point difference between a path with and without government spending shocks. Output is the difference between two paths scaled by the SSS values. Fiscal multiplier is the cumulative multiplier computed by equation (3.28).

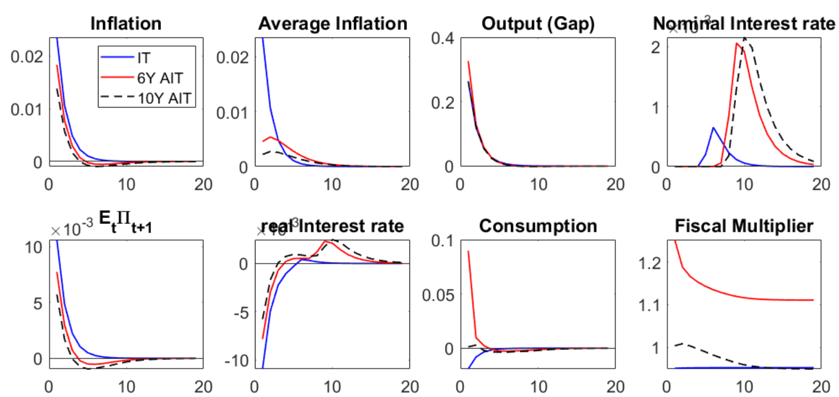
[Less persistent government spending shocks]

FIGURE A.5. Outside the ZLB



Note: Except for output, consumption and fiscal multiplier, the y-axis is the annualized percentage point difference between a path with and without government spending shocks. Output is the difference between two paths scaled by the SSS values. Fiscal multiplier is the cumulative multiplier computed by equation (3.28).

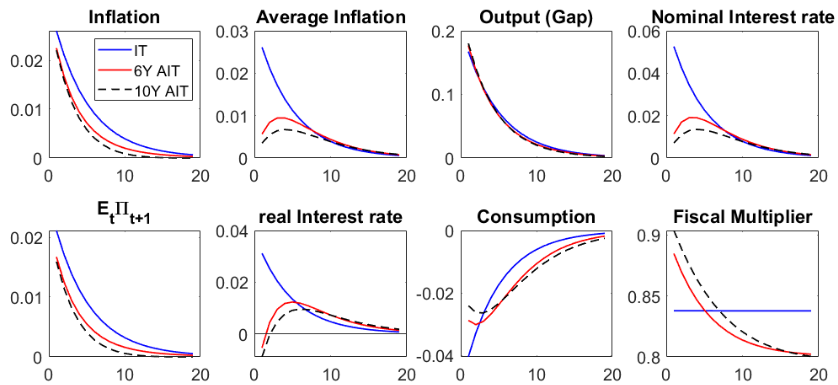
FIGURE A.6. At the ZLB



Note: Except for output, consumption and fiscal multiplier, the y-axis is the annualized percentage point difference between a path with and without government spending shocks. Output is the difference between two paths scaled by the SSS values. Fiscal multiplier is the cumulative multiplier computed by equation (3.28).

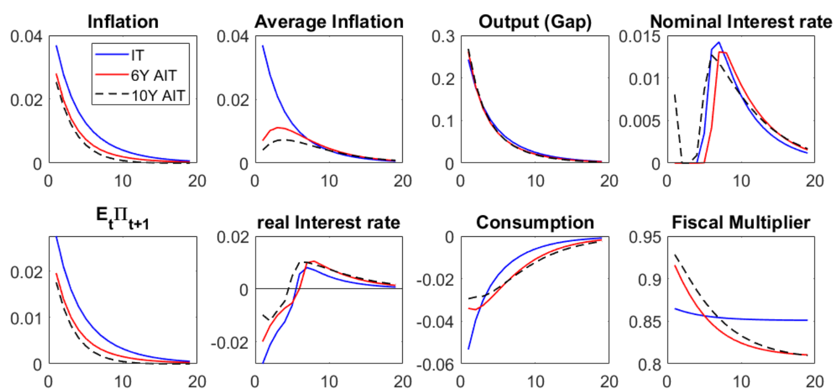
[Smaller response to inflation gap in monetary policy rule]

Figure A.7. Outside the ZLB



Note: Except for output, consumption and fiscal multiplier, the y-axis is the annualized percentage point difference between a path with and without government spending shocks. Output is the difference between two paths scaled by the SSS values. Fiscal multiplier is the cumulative multiplier computed by equation (3.28).

Figure A.8. At the ZLB



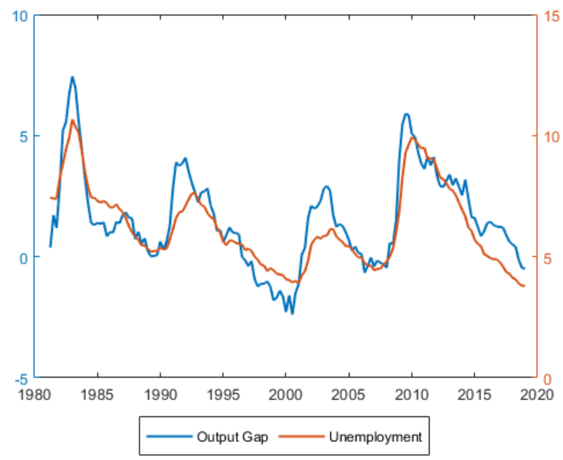
Note: Except for output, consumption and fiscal multiplier, the y-axis is the annualized percentage point difference between a path with and without government spending shocks. Output is the difference between two paths scaled by the SSS values. Fiscal multiplier is the cumulative multiplier computed by equation (3.28).

APPENDIX B

Chapter2 Appendix

B.1. Output gap vs Unemployment rate

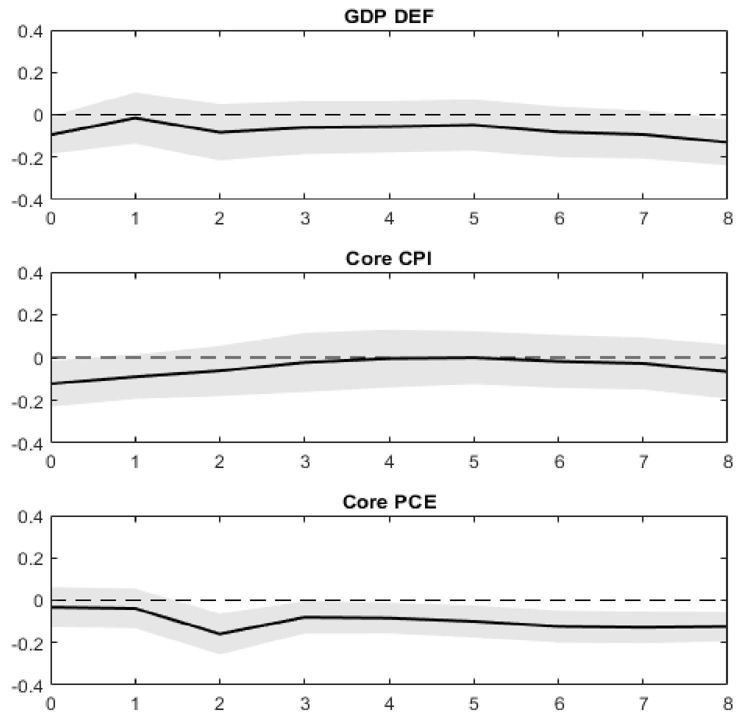
Figure B.1. Output gap vs Unemployment rate



Note: We use Congressional Budget Office(CBO) data for output gap. Unemployment rate comes from FRED. To compare output gap to unemployment rate, we change the sign of the output gap.

B.2. Response of inflation in the linear specification

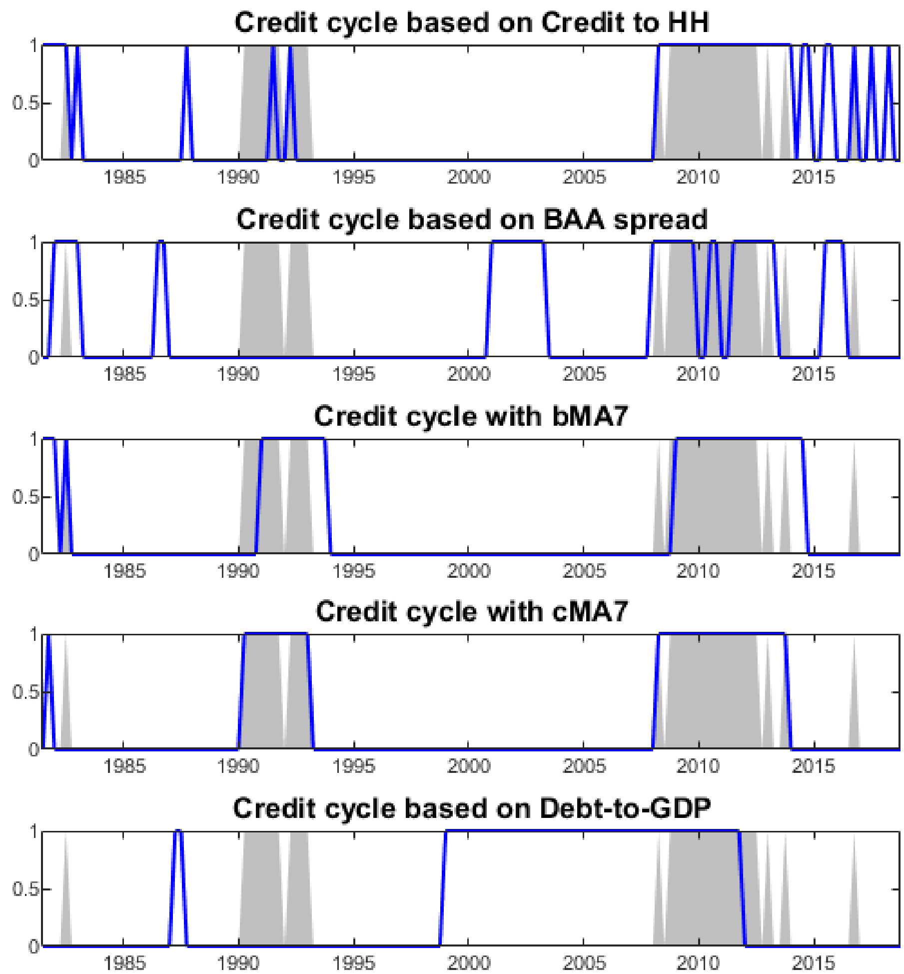
Figure B.2. Response of inflation to the baseline shocks



Note: Each row from the above plots the responses of GDP deflator, core CPI and core PCE to the baseline government spending shocks, respectively. Shaded areas are one standard confidence intervals.

B.3. Alternative credit cycles

Figure B.3. Credit cycles with alternative definitions



Note: Shaded area is the credit recession of baseline definition. Blue lines in each row represents the credit recession of alternative definitions.

APPENDIX C

Chapter3 Appendix

C.1. Nonlinear Solution Method

Here, I explain how I solve the model. Below are the equilibrium conditions from the baseline model.

$$\frac{1}{c_t} = E_t\left[\beta_{t+1}\frac{1}{c_{t+1}}\frac{R_t}{\Pi_{t+1}}\right] \tag{C.1}$$

$$\psi l_t^{\varphi} c_t = w_t \tag{C.2}$$

$$\epsilon x_{1,t} = (\epsilon - 1)x_{2,t} \tag{C.3}$$

$$x_{1,t} = \frac{w_t}{c_t} y_t + \theta E_t[\beta_{t+1}\Pi_{t+1}^{\epsilon} x_{1,t+1}] \tag{C.4}$$

$$x_{2,t} = \Pi_t^* \left(\frac{y_t}{c_t} + \theta E_t\left[\beta_{t+1}\frac{\Pi_{t+1}^{\epsilon-1}}{\Pi_{t+1}^*} x_{2,t+1}\right]\right) \tag{C.5}$$

$$R_t = max\left(elb(s(t)), R\left(\frac{\Pi_t}{\Pi}\right)^{\phi_\pi}\right) \tag{C.6}$$

$$g_t = s_{g,t} y_t \tag{C.7}$$

$$1 = \theta \Pi_t^{\epsilon-1} + (1-\theta)(\Pi_t^*)^{1-\epsilon} \tag{C.8}$$

$$v_t = \theta \Pi_t^{\epsilon} v_{t-1} + (1 - theta)(\Pi_t^*)^{-\epsilon} \tag{C.9}$$

$$y_t = c_t + g_t \tag{C.10}$$

$$y_t = \frac{l_t}{v_t} \tag{C.11}$$

$$\beta_t = \beta^{1-\rho_b}\beta_{t-1}^{\rho_b} exp(\sigma_b \epsilon_{b,t}) \tag{C.12}$$

$$s_{g,t} = s_g^{1-\rho_g} s_{g,t-1}^{\rho_g} exp(\sigma_g \epsilon_{g,t}) \tag{C.13}$$

I use time iteration with piecewise linear interpolation of policy functions as in Richter et al. (2014). Expectations are calculated based on Rouwenhorst (1995), which Kopecky and Suen (2010) show dominates other methods for approximating autoregressive processes.

There are 4 state variables in the system : β_t, $s_{g,t}$, v_{t-1} and $s(t)$, where $s(t)$ is a discrete stochastic variable. I choose l_t, $x_{1,t}$ and Π_t as policy variables to approximate:

$$l_t = g^1(\beta_t, s_{g,t}, v_{t-1}, s(t)) \tag{C.14}$$

$$x_{1,t} = g^2(\beta_t, s_{g,t}, v_{t-1}, s(t)) \tag{C.15}$$

$$\Pi_t = g^3(\beta_t, s_{g,t}, v_{t-1}, s(t)) \tag{C.16}$$

To solve the model, I approximate the unknown policy functions with piecewise linear functions $\tilde{g}^i$ that can be written as:

$$l_t = \tilde{g}^1(\beta_t, s_{g,t}, v_{t-1}, s(t)) \tag{C.17}$$

$$x_{1,t} = \tilde{g}^2(\beta_t, s_{g,t}, v_{t-1}, s(t)) \tag{C.18}$$

$$\Pi_t = \tilde{g}^3(\beta_t, s_{g,t}, v_{t-1}, s(t)) \tag{C.19}$$

Then, the time iteration algorithm is implemented as follows:

1. Define a discretized grid for the states.
2. Guess the piecewise linear policy functions $\tilde{g}^1$, $\tilde{g}^2$, $\tilde{g}^3$.
3. Given state vector, solve for time t policy variables:

$$l_t = \tilde{g}^1(\beta_t, s_{g,t}, v_{t-1}, s(t)) \tag{C.20}$$

$$x_{1,t} = \tilde{g}^2(\beta_t, s_{g,t}, v_{t-1}, s(t)) \tag{C.21}$$

$$\Pi_t = \tilde{g}^3(\beta_t, s_{g,t}, v_{t-1}, s(t)) \tag{C.22}$$

then, the remaining variables are given as:

$$x_{2,t} = \Pi_t^* \left(\frac{y_t}{c_t} + \theta E_t \left[\beta_{t+1} \frac{\Pi_{t+1}^{\epsilon-1}}{\Pi_{t+1}^*} x_{2,t+1} \right] \right) \tag{C.23}$$

$$\Pi_t^* = ((1 - \theta * \Pi_t^(\epsilon - 1))/(1 - \theta))^(1/(1 - \epsilon)) \tag{C.24}$$

$$v_t = \theta \Pi_t^\epsilon v_{t-1} + (1 - theta)(\Pi_t^*)^{-\epsilon} \tag{C.25}$$

$$y_t = \frac{l_t}{v_t} \tag{C.26}$$

$$g_t = s_{g,t} y_t \tag{C.27}$$

$$c_t = y_t - g_t \tag{C.28}$$

$$w_t = \psi l_t^\varphi c_t \tag{C.29}$$

$$R_t = max \left(elb(s(t)), R \left(\frac{\Pi_t}{\Pi} \right)^{\phi_\pi} \left(\frac{y_t}{y} \right)^{\phi_y} \right) \tag{C.30}$$

For each node of future shocks β_{t+1}^i $s_{g,t+1}$, calculate the next period policy variables,

$$l_{t+1} = \tilde{g}^1(\beta_{t+1}, s_{g,t+1}, v_t, s(t+1)) \tag{C.31}$$

$$x_{1,t+1} = \tilde{g}^2(\beta_{t+1}, s_{g,t+1}, v_t, s(t+1)) \tag{C.32}$$

$$\Pi_{t+1} = \tilde{g}^3(\beta_{t+1}, s_{g,t+1}, v_t, s(t+1)) \tag{C.33}$$

and $x_{2,t+1}$ and c_{t+1}. Since the model contains discrete stochastic state variable $s(t)$ as well as continuous variables, the integration is computed as follows: first integrate across the continuous random variables to obtain a set of values, conditional on the realization of the discrete stochastic variable. Then, weight each of these values by their corresponding probability. This procedure yields an expected value across all stochastic components in the model.

Next, derive the errors for the Euler Equation, the equations for the auxiliary variables $x_{1,t}$ and $x_{2,t}$:

$$err_1 = 1 - c_t E_t \left[\beta_{t+1} \frac{1}{c_{t+1}} \frac{R_t}{\Pi_{t+1}} \right] \tag{C.34}$$

$$err_2 = 1 - \frac{1}{x_{1,t}} \left(\frac{w_t}{c_t} y_t + \theta E_t [\beta_{t+1} \Pi_{t+1}^{\epsilon} x_{1,t+1}] \right) \tag{C.35}$$

$$err_3 = 1 - \frac{\Pi_t^*}{x_{2,t}} \left(\frac{y_t}{c_t} + \theta E_t \left[\beta_{t+1} \frac{\Pi_{t+1}^{\epsilon-1}}{\Pi_{t+1}^*} x_{2,t+1} \right] \right) \tag{C.36}$$

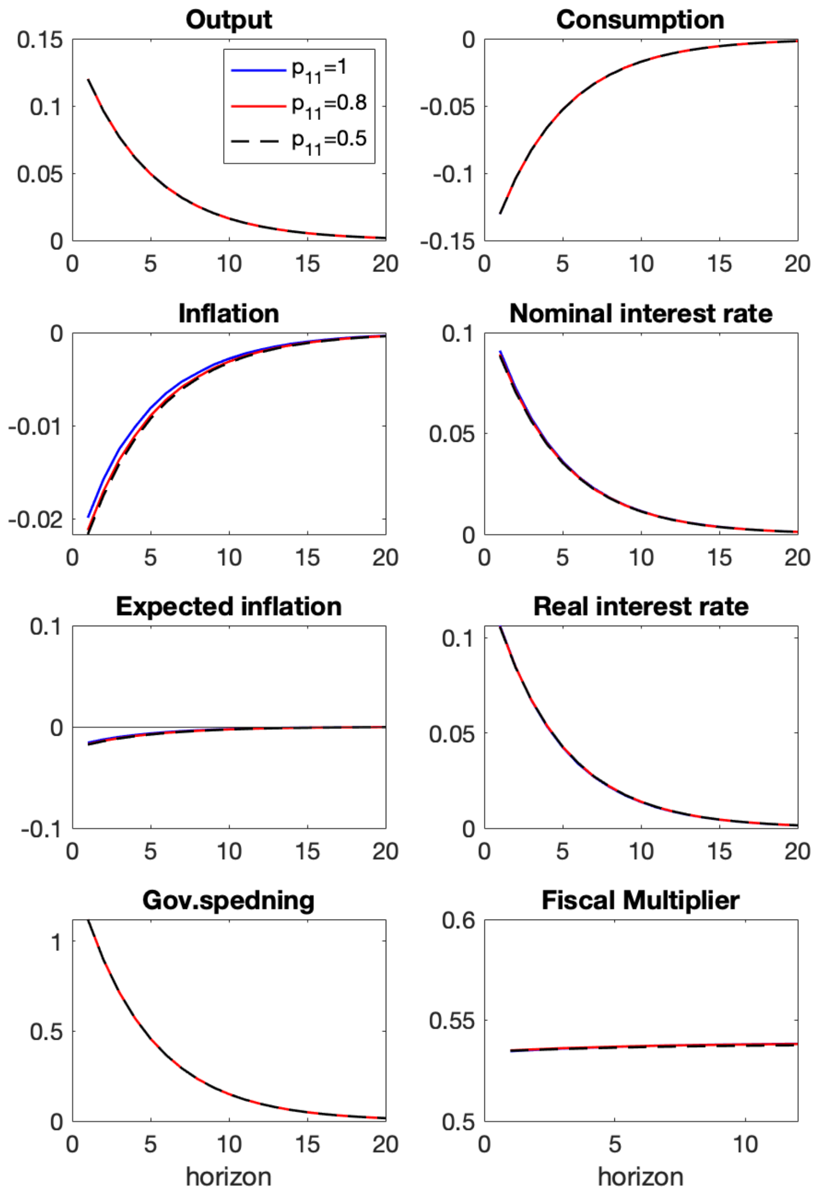
4. Use Chris Sims's *csolve* to find a root which minimizes the above errors.
5. Repeat step 2-4 until $maxdist < 10^{-5}$, where $maxdist = \max\{|l_t^i - l_t^{i-1}|, |x_{1,t}^i - x_{1,t}^{i-1}|, |\Pi_t^i - \Pi_t^{i-1}|\}$. When that criterion is satisfied, the algorithm has converged to an approximate nonlinear solution.

C.2. Generalized Impulse Response Functions

I follow Koop et al. (1996) to produce GIRFs. The GIRFs are derived from the average path from repeated model simulations and calculated as follows:

1. Feed the initial state vector into each simulation. A common initial state is a stochastic steady state.
2. Draw random preference shocks and government spending shocks $\{\beta_t, s_{g,t}\}_{t=0}^{N}$for each simulation where N is the horizon of simulation. From the initial state vector, simulate the model $R(= 1,000)$ times. Thus, we have R random draw series with N horizon each.
3. Using the same R draws of shock from step 2, replace the government spending shock in period one with a size of shock interested in. Then, simulate the model with these alternate sequences of shocks to obtain R equilibrium paths.
4. Average across the R simulations from step 2 and 3 to obtain an average paths.
5. The difference between these two series is a GIRF.

C.3. GIRFs outside the ZLB



Note: The blue line corresponds to the case of $p_{11} = 1$, the red line is for $p_{11} = 0.8$ and the black dashed line represents the case of $p_{11} = 0.5$. Inflation, nominal interest rate, expected inflation and real interest rate are expressed in terms of the annualized percentage points. The remaining variables except for fiscal multiplier are expressed as the percentage changes.

Bibliography

Adam, K. and Billi, R. M. (2007). Discretionary monetary policy and the zero lower bound on nominal interest rates. *Journal of monetary Economics*, 54(3):728–752.

Albertini, J., Auray, S., Bouakez, H., and Eyquem, A. (2021). Taking off into the wind: Unemployment risk and state-dependent government spending multipliers. *Journal of monetary economics*, 117:990–1007.

Alloza, M. (2017). Is fiscal policy more effective in uncertain times or during recessions?

Amano, R. A., Gnocchi, S., Leduc, S., and Wagner, J. (2020). Average is good enough: Average-inflation targeting and the elb. Technical report, Bank of Canada Staff Working Paper.

Andrade, P., Galí, J., Le Bihan, H., and Matheron, J. (2021). Should the ecb adjust its strategy in the face of a lower r? *Journal of Economic Dynamics and Control*, 132:104207.

Auerbach, A. J. and Gorodnichenko, Y. (2012). Measuring the output responses to fiscal policy. *American Economic Journal: Economic Policy*, 4(2):1–27.

Auerbach, A. J. and Gorodnichenko, Y. (2013). Output spillovers from fiscal policy. *American Economic Review*, 103(3):141–46.

Auerbach, A. J. and Gorodnichenko, Y. (2017). Fiscal stimulus and fiscal sustainability. Technical report, National Bureau of Economic Research.

Bachmann, R. and Sims, E. R. (2012). Confidence and the transmission of government spending shocks. *Journal of Monetary Economics*, 59(3):235–249.

Barnichon, R., Debortoli, D., and Matthes, C. (2022). Understanding the size of the government spending multiplier: It's in the sign. *The Review of Economic Studies*, 89(1):87–117.

Barro, R. J. and Redlick, C. J. (2011). Macroeconomic effects from government purchases and taxes. *The Quarterly Journal of Economics*, 126(1):51–102.

Ben Zeev, N. and Pappa, E. (2017). Chronicle of a war foretold: The macroeconomic effects of anticipated defence spending shocks. *The Economic Journal*, 127(603):1568–1597.

Bernardini, M. and Peersman, G. (2018). Private debt overhang and the government spending multiplier: Evidence for the united states. *Journal of Applied Econometrics*, 33(4):485–508.

Bianchi, F., Melosi, L., and Rottner, M. (2021). Hitting the elusive inflation target. *Journal of Monetary Economics*, 124:107–122.

Bilbiie, F. O., Meier, A., and Müller, G. J. (2008). What accounts for the changes in us fiscal policy transmission? *Journal of Money, Credit and Banking*, 40(7):1439–1470.

Blanchard, O. and Perotti, R. (2002). An empirical characterization of the dynamic effects of changes in government spending and taxes on output. *the Quarterly Journal of economics*, 117(4):1329–1368.

Boneva, L. M., Braun, R. A., and Waki, Y. (2016). Some unpleasant properties of loglinearized solutions when the nominal rate is zero. *Journal of Monetary Economics*, 84:216–232.

Borsi, M. T. (2018). Fiscal multipliers across the credit cycle. *Journal of Macroeconomics*, 56:135–151.

Bottero, M., Minoiu, C., Peydró, J.-L., Polo, A., Presbitero, A. F., and Sette, E. (2021). Expansionary yet different: credit supply and real effects of negative interest rate policy. *Journal of Financial Economics*.

Braun, R., Koerber, L., and Waki, Y. (2013). Small and orthodox fiscal multipliers at the zero lower bound. *FRB Atlanta Working Paper*.

Brückner, M. and Pappa, E. (2012). Fiscal expansions, unemployment, and labor force participation: Theory and evidence. *International Economic Review*, 53(4):1205–1228.

Brunnermeier, M. K. and Koby, Y. (2018). The reversal interest rate. Technical report, National Bureau of Economic Research.

Budianto, F., Nakata, T., and Schmidt, S. (2020). Average inflation targeting and the interest rate lower bound. *BIS Working Paper*.

Burnside, C., Eichenbaum, M., and Fisher, J. D. (2004). Fiscal shocks and their consequences. *Journal of Economic theory*, 115(1):89–117.

Caggiano, G., Castelnuovo, E., Colombo, V., and Nodari, G. (2015). Estimating fiscal multipliers: News from a non-linear world. *The Economic Journal*, 125(584):746–776.

Calvo, G. A. (1983). Staggered prices in a utility-maximizing framework. *Journal of monetary Economics*, 12(3):383–398.

Canzoneri, M., Collard, F., Dellas, H., and Diba, B. (2016). Fiscal multipliers in recessions. *The Economic Journal*, 126(590):75–108.

Christiano, L., Eichenbaum, M., and Rebelo, S. (2011). When is the government spending multiplier large? *Journal of Political Economy*, 119(1):78–121.

Coenen, G., Montes-Galdon, C., and Schmidt, S. (2021). Macroeconomic stabilisation and monetary policy effectiveness in a low-interest-rate environment. *Journal of Economic Dynamics and Control*, 132:104205.

Corsetti, G., Meier, A., and Müller, G. J. (2012). What determines government spending multipliers? *Economic Policy*, 27(72):521–565.

Crafts, N. and Mills, T. C. (2013). Fiscal policy in a depressed economy: Was there a'free lunch'in 1930s' britain? *CEPR Discussion Paper No. DP9273*.

Davig, T., Leeper, E. M., Clarida, R. H., and Lindé, J. (2006). Endogenous monetary policy regime change [with comments]. In *NBER international seminar on macroeconomics*, volume 2006, pages 345–391. The University of Chicago Press Chicago, IL.

De Cos, P. H. and Moral-Benito, E. (2016). Fiscal multipliers in turbulent times: the case of spain. *Empirical Economics*, 50(4):1589–1625.

De Groot, O. and Haas, A. (2022). The signalling channel of negative interest rates.

Del Negro, M., Giannone, D., Giannoni, M. P., and Tambalotti, A. (2019). Global trends in interest rates. *Journal of International Economics*, 118:248–262.

Eggertsson, G. B. (2011). What fiscal policy is effective at zero interest rates? *NBER Macroeconomics Annual*, 25(1):59–112.

Eggertsson, G. B., Juelsrud, R. E., Summers, L. H., and Wold, E. G. (2019). Negative nominal interest rates and the bank lending channel. Technical report, National Bureau of Economic Research.

Eggertsson, G. B. and Krugman, P. (2012). Debt, deleveraging, and the liquidity trap: A fisher-minsky-koo approach. *The Quarterly Journal of Economics*, 127(3):1469–1513.

Eggertsson, G. B. and Singh, S. R. (2019). Log-linear approximation versus an exact solution at the zlb in the new keynesian model. *Journal of Economic Dynamics and Control*, 105:21–43.

Fazzari, S. M., Morley, J., and Panovska, I. (2018). When is discretionary fiscal policy effective? *Available at SSRN 2921667*.

Fernández-Villaverde, J., Gordon, G., Guerrón-Quintana, P., and Rubio-Ramirez, J. F. (2015). Nonlinear adventures at the zero lower bound. *Journal of Economic Dynamics and Control*, 57:182–204.

Ferraresi, T., Roventini, A., and Fagiolo, G. (2015). Fiscal policies and credit regimes: a tvar approach. *Journal of Applied Econometrics*, 30(7):1047–1072.

Fisher, J. D. and Peters, R. (2010). Using stock returns to identify government spending shocks. *The Economic Journal*, 120(544):414–436.

FOMC (2022). Statement on longer-run goals and monetary policy strategy.

Galí, J., López-Salido, J. D., and Vallés, J. (2007). Understanding the effects of government spending on consumption. *Journal of the european economic association*, 5(1):227–270.

Glocker, C., Sestieri, G., and Towbin, P. (2019). Time-varying government spending multipliers in the uk. *Journal of Macroeconomics*, 60:180–197.

Guerrieri, L. and Iacoviello, M. (2015). Occbin: A toolkit for solving dynamic models with occasionally binding constraints easily. *Journal of Monetary Economics*, 70:22–38.

Hall, R. E. (2009). By how much does gdp rise if the government buys more output? Technical report, National Bureau of Economic Research.

Hazell, J., Herreno, J., Nakamura, E., and Steinsson, J. (2020). The slope of the phillips curve: evidence from us states. Technical report, National Bureau of Economic Research.

Hills, T. S. and Nakata, T. (2018). Fiscal multipliers at the zero lower bound: the role of policy inertia. *Journal of Money, Credit and Banking*, 50(1):155–172.

Holston, K., Laubach, T., and Williams, J. C. (2017). Measuring the natural rate of interest: International trends and determinants. *Journal of International Economics*, 108:S59–S75.

Horvath, R., Kaszab, L., Marsal, A., and Rabitsch, K. (2020). Determinants of fiscal multipliers revisited. *Journal of Macroeconomics*, 63:103162.

Hussain, S. and Liu, L. (2018). Macroeconomic effects of government spending shocks: New narrative evidence from canada. *Available at SSRN 3297476*.

Ilzetzki, E., Mendoza, E. G., and Végh, C. A. (2013). How big (small?) are fiscal multipliers? *Journal of monetary economics*, 60(2):239–254.

Jordà, Ò. (2005). Estimation and inference of impulse responses by local projections. *American economic review*, 95(1):161–182.

Jordà, Ò., Schularick, M., and Taylor, A. M. (2013). When credit bites back. *Journal of Money, Credit and Banking*, 45(s2):3–28.

Kiley, M. T. (2016). Policy paradoxes in the new keynesian model. *Review of Economic Dynamics*, 21:1–15.

Kimball, M. S. (1995). The quantitative analytics of the basic neomonetarist model. *Journal of Money, Credit and Banking*, 27(4):1241–1277.

Koop, G., Pesaran, M. H., and Potter, S. M. (1996). Impulse response analysis in nonlinear multivariate models. *Journal of econometrics*, 74(1):119–147.

Kopecky, K. A. and Suen, R. M. (2010). Finite state markov-chain approximations to highly persistent processes. *Review of Economic Dynamics*, 13(3):701–714.

Leeper, E. M., Traum, N., and Walker, T. B. (2017). Clearing up the fiscal multiplier morass. *American Economic Review*, 107(8):2409–54.

Lindé, J. and Trabandt, M. (2018). Should we use linearized models to calculate fiscal multipliers? *Journal of Applied Econometrics*, 33(7):937–965.

Lopez, J. A., Rose, A. K., and Spiegel, M. M. (2020). Why have negative nominal interest rates had such a small effect on bank performance? cross country evidence. *European Economic Review*, 124:103402.

McManus, R., Ozkan, F. G., and Trzeciakiewicz, D. (2018). Why are fiscal multipliers asymmetric? the role of credit constraints. *The Role of Credit Constraints (October 7, 2018)*.

Mertens, K. and Ravn, M. O. (2014a). A reconciliation of svar and narrative estimates of tax multipliers. *Journal of Monetary Economics*, 68:S1–S19.

Mertens, K. R. and Ravn, M. O. (2014b). Fiscal policy in an expectations-driven liquidity trap. *The Review of Economic Studies*, 81(4):1637–1667.

Mertens, T. M. and Williams, J. C. (2019). Tying down the anchor: monetary policy rules and the lower bound on interest rates. *FRB of New York Staff Report*, (887).

Michaillat, P. (2014). A theory of countercyclical government multiplier. *American Economic Journal: Macroeconomics*, 6(1):190–217.

Miyamoto, W., Nguyen, T. L., and Sergeyev, D. (2018). Government spending multipliers under the zero lower bound: Evidence from japan. *American Economic Journal: Macroeconomics*, 10(3):247–77.

Nakata, T. (2017). Uncertainty at the zero lower bound. *American Economic Journal: Macroeconomics*, 9(3):186–221.

Nakov, A. (2008). Optimal and simple monetary policy rules with zero floor on the nominal interest rate. *International Journal of Central Banking*.

Nessén, M. and Vestin, D. (2005). Average inflation targeting. *Journal of Money, credit and Banking*, pages 837–863.

Olea, J. L. M. and Pflueger, C. (2013). A robust test for weak instruments. *Journal of Business & Economic Statistics*, 31(3):358–369.

Owyang, M. T., Ramey, V. A., and Zubairy, S. (2013). Are government spending multipliers greater during periods of slack? evidence from twentieth-century historical data. *American Economic Review*, 103(3):129–34.

Perotti, R. (2005). Estimating the effects of fiscal policy in oecd countries.

Perotti, R. (2014). Defense government spending is contractionary, civilian government spending is expansionary. Technical report, National Bureau of Economic Research.

Ramey, V. A. (2011). Identifying government spending shocks: It's all in the timing. *The Quarterly Journal of Economics*, 126(1):1–50.

Ramey, V. A. (2019). Ten years after the financial crisis: What have we learned from the renaissance in fiscal research? *Journal of Economic Perspectives*, 33(2):89–114.

Ramey, V. A. and Shapiro, M. D. (1998). Costly capital reallocation and the effects of government spending. In *Carnegie-Rochester Conference Series on Public Policy*, volume 48, pages 145–194. Elsevier.

Ramey, V. A. and Zubairy, S. (2018). Government spending multipliers in good times and in bad: evidence from us historical data. *Journal of Political Economy*, 126(2):850–901.

Reinhart, C. M. and Rogoff, K. S. (2008). This time is different: A panoramic view of eight centuries of financial crises. Technical report, National Bureau of Economic Research.

Reinhart, C. M. and Rogoff, K. S. (2009). The aftermath of financial crises. *American Economic Review*, 99(2):466–72.

Richter, A. W., Throckmorton, N. A., and Walker, T. B. (2014). Accuracy, speed and robustness of policy function iteration. *Computational Economics*, 44(4):445–476.

Rotemberg, J. J. (1982). Sticky prices in the united states. *Journal of political economy*, 90(6):1187–1211.

Rouwenhorst, K. G. (1995). Asset pricing implications of equilibrium business cycle models. *Frontiers of business cycle research*, 1:294–330.

Schmitt-Grohé, S. and Uribe, M. (2007). Optimal simple and implementable monetary and fiscal rules. *Journal of monetary Economics*, 54(6):1702–1725.

Schularick, M. and Taylor, A. M. (2012). Credit booms gone bust: Monetary policy, leverage cycles, and financial crises, 1870-2008. *American Economic Review*, 102(2):1029–61.

Shen, W. and Yang, S.-C. S. (2018). Downward nominal wage rigidity and state-dependent government spending multipliers. *Journal of Monetary Economics*, 98:11–26.

Sims, E. and Wolff, J. (2018). The output and welfare effects of government spending shocks over the business cycle. *International Economic Review*, 59(3):1403–1435.

Sims, E. and Wu, J. C. (2021a). Evaluating central banks' tool kit: Past, present, and future. *Journal of Monetary Economics*, 118:135–160.

Sims, E. and Wu, J. C. (2021b). Evaluating central banks' tool kit: Past, present, and future. *Journal of Monetary Economics*, 118:135–160.

Stock, J. H. and Watson, M. W. (2020). Slack and cyclically sensitive inflation. *Journal of Money, Credit and Banking*, 52(S2):393–428.

Svensson, L. E. (2020). Monetary policy strategies for the federal reserve. Technical report, National Bureau of Economic Research.

Tagkalakis, A. (2008). The effects of fiscal policy on consumption in recessions and expansions. *Journal of Public economics*, 92(5-6):1486–1508.

Ulate, M. (2021). Going negative at the zero lower bound: The effects of negative nominal interest rates. *American Economic Review*, 111(1):1–40.

Woodford, M. (2011). Simple analytics of the government expenditure multiplier. *American Economic Journal: Macroeconomics*, 3(1):1–35.