

ARTICLE

# Government spending multipliers with the *Real Cost channel*\*

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## Abstract

In the benchmark New Keynesian (NK) model, I introduce the real cost channel to study government spending multipliers and provide simple Markov chain closed-form solutions. This model departs fundamentally from most previous interpretations of the nominal cost channel by flattening the NK Phillips Curve in liquidity traps. At the zero lower bound, I show analytically that following positive government spending shocks, the real cost channel can make inflation rise less than in a model without this channel. This then causes a smaller drop in real interest rates, resulting in a lower output gap multiplier. Finally, I confirm the robustness of the real cost channel's effect on multipliers using extensions of two models.

**Keywords:** Government spending multipliers; real cost channel; zero lower bound; Markov chain; bounded rationality

## 1. Introduction

In late 2008, the Federal Reserve had to lower the interest rate to zero to combat the Global Financial Crisis (GFC). Conventional monetary policy cannot work with a binding zero lower bound (ZLB). Therefore, the government sought to adopt an alternative effective fiscal policy to stimulate the economy during recessions. In this case, the GFC and subsequent recent recessions resulting from COVID-19 have sparked extensive fiscal policy discussions, which usually feature massive government spending.<sup>1</sup> For example, during the COVID-19 pandemic of 2020, the United States (US) government spent a total of \$6.55 trillion on a series of programs to ensure the well-being of its population.

Understanding the effects of government spending at the ZLB warrants a thorough fiscal analysis. Standard New Keynesian (NK) models show that government spending multipliers can be substantially higher (e.g. above 2) at the ZLB as in Eggertsson and Woodford (2004), Christiano et al. (2011) and Zubairy (2014). This view has been challenged in recent theoretical studies.<sup>2</sup> In addition, a series of new empirical papers have indicated that multipliers are lower at the ZLB. For instance, Ramey and Zubairy (2018) use US quarterly data spanning major wars and deep recessions to suggest government spending multipliers can be below 1 regardless of economic slack or near-zero rates, though estimates are more mixed at the ZLB, with a few specifications implying multipliers up to 1.5. Recently, Auerbach et al. (2021) show that fiscal multipliers can be lower if used along with post-COVID supply-side constraints during recessions.

In this paper, I use a benchmark NK model with the cost channel of the expected real interest rate to provide new theoretical insights that explain, consistent with empirical papers,

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lower government spending multipliers when the economy is at the ZLB. More specifically, if firms need to borrow in advance to finance production, the interest rate can theoretically influence borrowing costs and firms' marginal costs in the aggregate supply-side economy (summarized in the NK Phillips Curve). The critical difference between the model with the cost channel and the conventional model is that the interest rate should be included in firms' marginal costs which can, in turn, influence the inflation rate.

The existence of the cost channel is shown in some empirical investigations. For instance, Ravenna and Walsh (2006) estimate and obtain the cost channel parameter for the USA. Similarly, Chowdhury et al. (2006) and Tillmann (2009) show the existence of the cost channel in both the USA and the UK. Recently, Abo-Zaid (2022) employs a structural vector autoregression model to confirm that the cost channel exists in almost all representative industrialized countries.

Unlike most previous literature that focuses on the nominal cost channel,<sup>3</sup> this paper uses the real cost channel: Firms' marginal costs depend on expected real interest rates.<sup>4</sup> Furthermore, I conduct an analytical study on spending multipliers in liquidity traps. To this end, a simple two-state Markov chain, as in Eggertsson and Woodford (2003), is utilized to obtain closed-form solutions of spending multipliers.

At the ZLB, the results in this paper stand in stark contrast to most previous interpretations of the nominal cost channel as in Ravenna and Walsh (2006). I show that the introduced real cost channel can rotate the NK Phillips Curve with the expected disinflation effects during episodes of liquidity traps. The threshold of a negative natural rate shock to trigger ZLB constraints binding with the real cost channel is larger than in the classical NK model without the cost channel but less than in the model with the nominal cost channel. Therefore, the economy with the nominal cost channel is the most easily entrapped in liquidity traps.

Spending multipliers can be effective (larger than one) in liquidity traps. Intuitively, with ZLB binding, nominal interest rates remain unchanged. Government spending within a fiscal policy package can increase inflation in the short run. This can lower real interest rates and stimulate private consumption. However, the expected disinflation effects of the real cost channel result in lower marginal costs, causing inflation to rise by less than in standard models without it. Moreover, marginal costs can decrease even further with the increased strength of this channel. In this way, the real cost channel leads to a smaller drop in real interest rates. Higher real interest rates can depress people's appetite for consumption and production activity, which, in turn, can lower the output gap multiplier. On the other hand, spending multipliers with the nominal cost channel can be invariant with the standard NK model since this nominal channel cannot modify the NK Phillips Curve slope at the ZLB.<sup>5</sup> In a nutshell, the output gap multiplier with the real cost channel model is smaller at the ZLB and decreases with an increase in channel strength, compared to the standard NK model and nominal cost channel models.

Additionally, I find that the output gap multiplier decreases as the strength of the real cost channel increases in normal times. Government spending can increase inflation in the short run. The real cost channel can further increase inflation due to higher borrowing costs, and this effect can be amplified with the strengthening of this channel's impact. When nominal interest rates are free to adjust, the central bank increases rates more than inflation. The ensuing higher real interest rates curb private consumption, decreasing the output gap multiplier relative to a standard model without this channel, consistent with Abo-Zaid (2022). The nominal cost channel generates greater inflation than the real cost channel. Therefore, the nominal cost channel dampens the effects of government spending compared to the real cost channel.

This model extends to more general settings, with the real cost channel remaining robust. I analytically examine the effects of long-run government spending using a three-state Markov chain, as in Rouleau-Pasdeloup (2023), by assuming that government spending outlasts economic recessions. Prolonged spending in normal times deflates the output gap multiplier but raises the

inflation multiplier; in liquidity traps, it increases inflation through rational expectations, inflating the output gap multiplier.

As an extension, I explore introducing bounded rationality [Gabaix (2020)] into the baseline model to analyze the multiplier.<sup>6</sup> I find that bounded rationality in normal times eases inflation and increases the output gap multiplier. Sufficiently strong cognitive discounting greatly boosts it. At the ZLB, bounded rationality decreases the output gap multiplier. Besides, the real cost channel can still operate robustly in this behavioral model.

### 1.1. Related literature

Seminal work focusing on the theoretical estimation of government spending effects in liquidity traps can be traced to Eggertsson (2001). In this paper, the optimal fiscal policy in the NK economy is characterized, and the real effects of government spending are emphasized. Since then, an increasing amount of the literature has focused on the estimation of fiscal effects in theoretical and empirical settings. For example, Blanchard and Perotti (2002) spark the earliest insights on empirically estimating the macroeconomic effects of government spending.<sup>7</sup> Christiano et al. (2011) prove that the multiplier is low in normal times in an economy following a Taylor (1993)-type rule but relatively high in liquidity traps. Leeper et al. (2017) study fiscal multipliers theoretically in a series of models. Two distinct monetary-fiscal policy regimes show that the short-run multiplier is robustly similar across different regimes. There are more examples among Kraay (2012), Miyamoto et al. (2018), Ramey and Zubairy (2018), etc.

In this paper, I add to the government spending multiplier literature by analytically addressing the role of the real cost channel on multipliers. The previous literature as in Barth III and Ramey (2001), Ravenna and Walsh (2006), Llosa and Tuesta (2009), and Smith (2016) introduces the nominal cost channel: Firms' marginal costs augment nominal interest rates. For example, Ravenna and Walsh (2006) confirm that cost-push shocks can emerge endogenously in the NK model with the nominal cost channel. Surico (2008) shows that limiting the economic cycle with the cost channel can lead to strong fluctuations in inflation and output. Recent studies have investigated the role of the real cost channel in macroeconomic dynamics. For example, Beaudry et al. (2022) demonstrate that the Phillips curve appears quite flat when accounting for the real cost channel. Moreover, this study identifies a critical condition in which monetary loosening can lead to low-inflation traps when the real cost channel is present. Nie (2021) investigates the macroeconomic effects of tax shocks in models that incorporate the real cost channel. Inspired by their work, I modify the standard NK model by introducing expected real interest rates into firms' marginal costs to study multipliers.

This paper allies closely with some recent literature that uses a three-state Markov chain to analytically examine the macroeconomic effects of long-run policy on the short-run economy [see Bilbiie (2019a), Bilbiie (2019b), Bilbiie (2020) and Nie and Roulleau-Pasdeloup (2023)]. For example, Bilbiie (2019b) employs a three-state Markov chain for his in-depth study on the optimal forward guidance policy in both the short and long run. In this paper, a three-state structure can allow us to analytically check the general properties of long-run government spending to echo some empirical evidence in Durevall and Henrekson (2011), Ilzetzki et al. (2013), Leduc and Wilson (2013), Bouakez et al. (2017), and Yaffe (2019).

In addition, recent contributions such as Farhi and Werning (2019) and Gabaix (2020) show that bounded rationality mitigates the effects of monetary policy. This approach can rationalize the so-called "forward guidance puzzle" [see Angeletos and Lian (2018) and Coibion et al. (2020)] compared to the benchmark forward-looking NK model. This paper, however, is linked with this strand of literature and comments on the interaction of the cost channel and bounded rationality on fiscal policy.

Finally, this paper is also closely related to Abo-Zaid (2022) who examines government spending multipliers at the ZLB with the nominal cost channel. Abo-Zaid (2022) includes the nominal

cost channel and differentiates between the policy rate and loan rate. It turns out that this nominal channel can cause spending multipliers to be larger in liquidity traps. However, I adopt the real cost channel in this paper to explain lower government spending multipliers when the economy is at the ZLB. Simple Markov chain closed-form solutions are computed to study government spending multipliers with the real and nominal cost channels. Analytically, I further clarify the impact of the strength of the real cost channel on spending multipliers. I also study some extensions and confirm the robust role of the real cost channel on multipliers.

**1.2. Organization**

I specify the prototypical forward-looking NK model with the real cost channel in Section 2 and provide an analytical analysis using a two-state Markov chain on government spending multipliers. In Section 3, I study a baseline model to explore the general properties of long-run government spending effects. Another extension with bounded rationality is conducted in Section 4. Finally, this paper concludes in Section 5.

**2. The baseline model with the real cost channel**

Recent empirical evidence in Abo-Zaid (2022) shows that the existence of the cost channel can influence government spending multipliers. As in Ravenna and Walsh (2006) and Surico (2008), the main contribution of the cost channel is that the interest rate can influence borrowing costs and the marginal cost function. In this paper, I follow Beaudry et al. (2022) and Nie (2021) to utilize the NK model with the real cost channel specification, which means expected real interest rates can impact firms’ marginal costs and explore short-run government spending multipliers analytically.

**2.1. Private sector behavior**

I use a prototypical forward-looking NK model with the real cost channel as in Beaudry et al. (2022) and Nie (2021).<sup>8</sup> The behavior of the aggregate demand (AD) side of the economy can be summarized in the standard log-linearized Euler equation:

$$c_t = \mathbb{E}_t c_{t+1} - \frac{1}{\sigma_c} [R_t + \log(\beta) - \mathbb{E}_t \pi_{t+1} - r_t^n], \tag{1}$$

where  $c_t$  is private consumption,  $\sigma_c$  is the risk aversion coefficient,  $R_t$  is the nominal interest rate *in level*,  $\pi_t$  is inflation,  $\mathbb{E}_t$  is the rational expectation operator, and  $r_t^n$  is the demand shock (also the natural rate shock).

The linear resource constraint in this economy is

$$y_t = (1 - s_g)c_t + g_t, \tag{2}$$

where  $y_t$  is the output gap,  $s_g$  is the fraction of government spending in total production, and  $g_t$  is government spending.<sup>9</sup> In this case, one can obtain the path of  $y_t$  by substituting the resource constraint into the Euler equation below:

$$y_t = \mathbb{E}_t y_{t+1} - \frac{1}{\sigma} [R_t + \log(\beta) - \mathbb{E}_t \pi_{t+1} - r_t^n] + g_t - \mathbb{E}_t g_{t+1}, \tag{3}$$

where  $\sigma = \frac{\sigma_c}{1-s_g}$ .

The aggregate supply (AS) side of the economy can be summarized with the following log-linearized NK Phillips Curve.<sup>10</sup>

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \kappa [\gamma_y y_t + \gamma_g g_t + \gamma_r (R_t + \log(\beta) - \mathbb{E}_t \pi_{t+1})], \tag{4}$$

where  $\beta$  is the subjective discount factor, and  $\kappa$  is the elasticity of inflation with regard to marginal cost.  $\gamma_y$ ,  $\gamma_g$ , and  $\gamma_r$  are the elasticity of marginal cost elasticity with regard to the output gap, government spending, and the expected real interest rate, respectively.<sup>11</sup> It is of note that  $\gamma_r$  in equation (4) can be seen as the strength of the cost channel which controls the impact of this channel. This model with the real cost channel can collapse to the conventional one without the cost channel if  $\gamma_r = 0$ .<sup>12</sup> In addition, it can nest the model with the nominal cost channel [represented by equation (6)] if we assume that nominal interest rates are introduced in firms' borrowing costs as in Ravenna and Walsh (2006), and then, the expected disinflation term ( $-\mathbb{E}_t\pi_{t+1}$ ) of equation (4) disappears.

It is assumed that the central bank sets the nominal interest rate following the (truncated) Taylor (1993)-type rule with the ZLB:

$$R_t = \max\{0, -\log(\beta) + \phi_\pi \pi_t\}. \tag{5}$$

2.1.1. Real versus nominal cost channel

The Phillips Curve with the nominal cost channel is

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \kappa [\gamma_y y_t + \gamma_g g_t + \gamma_r (R_t + \log(\beta))]. \tag{6}$$

Equation (6) is used in most previous papers working as nominal cost channel specifications such as Ravenna and Walsh (2006) and Surico (2008). In these papers, the nominal interest rate is introduced in borrowing costs. Even though the specifications in equations (4) and (6) can be seen as the cost channel, the real cost channel specification in equation (4) features expected real interest rates in borrowing costs and highlights the additional role of expected disinflation denoted by the negative  $\mathbb{E}_t\pi_{t+1}$  term.

Note that the two cost channels can have similar effects in normal times if the central bank follows a simple Taylor rule in equation (5). In this case, a cost-push shock endogenously emerges in the two cases as in Ravenna and Walsh (2006), and the two channels both increase firms' marginal costs and inflation.

An interesting insight at the ZLB with  $R_t = 0$  is that the nominal cost channel as in Ravenna and Walsh (2006) and Surico (2008) cannot influence the slope of the Phillips Curve. However, note that, at the ZLB, the real cost channel as in Beaudry et al. (2022) can rotate the Phillips Curve with expectations of disinflation. As a result, the Phillips Curve with the real cost channel is flatter than in the standard NK model without this channel, and this may explain a declining slope of the empirical Phillips Curve.

2.2. Quick tour: normal times and ZLB

In this section, I employ a two-state static Markov chain as in Eggertsson et al. (2003) to deal with the policy shocks vector  $[r_t^n, g_t]$ . It is assumed that a specific policy shock (for example, the demand shock  $r_t^n$  in this vector) remains at the current short-run state (which I label  $r_S^n$  with a subscript 'S' for the short run) with a persistence  $p$  and then reverts to the long-run steady state, that is  $r_L^n = 0$  with a probability  $1 - p$ .<sup>13</sup> Since the NK model with the real cost channel in this paper is forward-looking, one can compute the expected output gap and inflation as follows:

$$\mathbb{E}_S y_{t+1} = p y_S, \quad \mathbb{E}_S \pi_{t+1} = p \pi_S. \tag{7}$$

**Assumption 1.** I assume that the NK Phillips Curve with the real cost channel is always upward sloping in a  $(\pi_S, y_S)$  graph such that

$$p < \frac{1 - \kappa \gamma_r \phi_\pi}{\beta - \kappa \gamma_r} = \bar{p}^c. \tag{8}$$

As proposed by Laubach and Williams (2003), Cochrane (2017), Han et al. (2020), and Nie and Roulleau-Pasdeloup (2023), there is an implicit condition that the NK Phillips Curve is upward sloping in a  $(\pi_S, y_S)$  graph as in Assumption 1. Compared with the NK model with the nominal cost channel as in Christiano et al. (2005) and Ravenna and Walsh (2006), this paper utilizes a more empirically relevant real cost channel proposed in Beaudry et al. (2022) and further extended in Nie (2021).

In this section, we discuss two cases which are the economy in normal times without ZLB binding and also in liquidity traps. There is a threshold of demand shock to trigger ZLB constraint binding. From the Taylor (1993)-type rule, one can see that if the item  $\{-\log(\beta) + \phi_\pi \pi_S\}$  is less than or equal to zero, the NK economy can be binding with the ZLB state. If not, the economy is in normal times and nominal interest rates can be free to adjust with the central bank’s monetary policy regulation. If the (negative) natural rate shock is too large, the economy can be caught up in liquidity traps. Thereby there is a boundary condition for the natural rate shock  $r_S^n$  in the short run to trigger the economy into a state with ZLB binding.

**Proposition 1.** *The boundary condition relationship among the three models is*

$$\underline{r_S^{n,B}} < \underline{r_S^n} < \underline{r_S^{n,N}}, \tag{9}$$

where  $\underline{r_S^{n,B}}$  is the boundary condition without the cost channel,  $\underline{r_S^n}$  is with the real cost channel, and  $\underline{r_S^{n,N}}$  is with the nominal cost channel.

*Proof.* See Online Appendix B. □

In Proposition 1, the boundary condition to trigger the ZLB binding with the real cost channel is larger than in the conventional NK model without the cost channel since the real cost channel features the supply-side effects of interest rates. In other words, the economy can get stuck more easily in liquidity traps with the real cost channel than in the traditional model. On the other hand, the boundary condition with the nominal cost channel is larger than in the model with the real cost channel due to expectations of disinflation. Therefore, among the three models, the model with the nominal cost channel is the most easily entrapped in liquidity traps.<sup>14</sup>

In the following sections, I will focus on government spending shocks and discuss the issues of the output gap and inflation multipliers.

**2.3. Government spending: theoretical analysis**

To obtain transparent results, I abstract from demand shocks and focus only on the effects of government spending shocks with the real cost channel. First, I compare the multiplier relationship among the three models. Second, I deliver the general property of the strength of the cost channel on the multiplier by using simple Markov chain closed-form solutions.

*2.3.1. Government spending multipliers in normal times*

I assume that a positive government spending shock  $g_S > 0$  follows the Markov process. It starts in the short run, stays with the persistence probability  $p$ , and returns to the steady-state  $g_L = 0$  in the long run with a probability  $1 - p$ . If the short-run economy is in normal times, I can rewrite the Euler equation (3) and the Phillips Curve with the real cost channel [equation (4)]:

$$y_S = -\frac{1}{\sigma(1-p)}(\phi_\pi - p)\pi_S + g_S \tag{10}$$

$$\pi_S = \kappa \frac{\gamma_y}{1 - \beta p - \kappa \gamma_r(\phi_\pi - p)} y_S + \kappa \frac{\gamma_g}{1 - \beta p - \kappa \gamma_r(\phi_\pi - p)} g_S. \tag{11}$$

*Fiscal multipliers.* I find that a positive government spending shock can move the Euler equation upward and shift down the Phillips Curve in a  $(\pi_t, y_t)$  graph. The solutions with the real cost channel of the output gap multiplier  $\mathcal{M}_{S,N}^O$  and inflation multiplier  $\mathcal{M}_{S,N}^I$  can be computed as follows:<sup>15</sup>

$$\mathcal{M}_{S,N}^O = \frac{\sigma(1-p)[1-\beta p - \kappa\gamma_r(\phi_\pi - p)] - \kappa\gamma_g(\phi_\pi - p)}{\sigma(1-p)[1-\beta p - \kappa\gamma_r(\phi_\pi - p)] + \kappa\gamma_y(\phi_\pi - p)} \tag{12}$$

$$\mathcal{M}_{S,N}^I = \frac{\left[1 + \frac{\gamma_g}{\gamma_y}\right]\kappa\gamma_y\sigma(1-p)}{\sigma(1-p)[1-\beta p - \kappa\gamma_r(\phi_\pi - p)] + \kappa\gamma_y(\phi_\pi - p)}. \tag{13}$$

The expected real interest rate can be in both the denominator and numerator of the output gap multiplier since the real cost channel here can influence the inflation rate and further impact the output gap through expectations. Regarding the inflation multiplier, the expected real interest rate is included in the denominator since the cost channel can impact this multiplier directly. In normal times, since the denominator of the multiplier equation is higher than the numerator, the multiplier is less than one.<sup>16</sup>

In normal times, the real cost channel reduces the output gap multiplier, consistent with Abo-Zaid (2022). Positive government spending shocks elevate short-run inflation;<sup>17</sup> the real cost channel further heightens borrowing costs and inflation.<sup>18</sup> With adjustable nominal interest rates, the central bank increases rates by more than inflation.<sup>19</sup> The ensuing higher real interest rates curb private consumption, decreasing the output gap multiplier compared to the scenario where this channel is absent.

As in Online Appendix C, compared to the nominal cost channel, the inflation multiplier with the real cost channel can be smaller. If we compare the NK Phillips Curve in equations (6) and (4), less influence is triggered by the real cost channel, which can echo the fact of lower inflation in the Euro area in normal times [Koester et al. (2021)]. In this scenario, the nominal cost channel can further reduce the output gap multiplier compared to the real cost channel.

I also explore the effects of the strength of the real cost channel  $\gamma_r$  on spending multipliers. The power of the real cost channel can directly leverage the increment of inflation. On the other hand, we can see that higher inflation can crowd out more private consumption, hence leading to a much lower output gap multiplier given a stronger real cost channel. Therefore, the output gap multiplier decreases in  $\gamma_r$ , whereas the inflation multiplier increases in  $\gamma_r$ . I summarize the above theoretical results in Proposition 2.

**Proposition 2.** *In normal times, the output gap multiplier  $\mathcal{M}_{S,N}^O$  decreases in  $\gamma_r$ , whereas the inflation multiplier  $\mathcal{M}_{S,N}^I$  increases in  $\gamma_r$ . The output gap multiplier relationship among the three models is*

$$\mathcal{M}_{S,N}^{O,N} < \mathcal{M}_{S,N}^O < \mathcal{M}_{S,N}^{O,B}, \tag{14}$$

and the inflation multiplier relationship is

$$\mathcal{M}_{S,N}^{I,B} < \mathcal{M}_{S,N}^I < \mathcal{M}_{S,N}^{I,N}, \tag{15}$$

where in normal times:  $\mathcal{M}_{S,N}^{O,B}$  is the output gap multiplier without the cost channel and  $\mathcal{M}_{S,N}^{O,N}$  is with the nominal cost channel;  $\mathcal{M}_{S,N}^{I,B}$  is the inflation multiplier without the cost channel, and  $\mathcal{M}_{S,N}^{I,N}$  is with the nominal cost channel.

*Proof.* See Online Appendix C. □

2.3.2. Government spending multipliers at ZLB

In this part, I focus on the case when the short-run economy is stuck at the ZLB.<sup>20</sup> The Euler equation (3) and the Phillips Curve with the real cost channel [equation (4)] can be rewritten as:

$$y_s = -\frac{1}{\sigma(1-p)}[\log(\beta) - p\pi_s] + g_s \tag{16}$$

$$\pi_s = \frac{\kappa\gamma_y}{1-\beta p + \kappa\gamma_r p}y_s + \kappa\frac{\gamma_g}{1-\beta p + \kappa\gamma_r p}g_s + \frac{\kappa\gamma_r \log(\beta)}{1-\beta p + \kappa\gamma_r p}. \tag{17}$$

*Fiscal multipliers.* In liquidity traps, one can use the Euler equation and the Phillips Curve to obtain the solutions with the real cost channel of the output gap multiplier  $\mathcal{M}_{S,Z}^O$  and the inflation multiplier  $\mathcal{M}_{S,Z}^I$ .<sup>21</sup>

$$\mathcal{M}_{S,Z}^O = \frac{\sigma(1-p)[1-\beta p + \kappa\gamma_r p] + \kappa\gamma_g p}{\sigma(1-p)(1-\beta p + \kappa\gamma_r p) - \kappa\gamma_y p} \tag{18}$$

$$\mathcal{M}_{S,Z}^I = \frac{\left[1 + \frac{\gamma_g}{\gamma_y}\right]\kappa\gamma_y\sigma(1-p)}{\sigma(1-p)(1-\beta p + \kappa\gamma_r p) - \kappa\gamma_y p}. \tag{19}$$

From the solutions, the expected real interest rate can be both the denominator and numerator of the output gap multiplier. The real cost channel here can influence the inflation rate and further impact the output gap through expectations. The real cost channel can impact the inflation multiplier directly through the NK Phillips Curve.

In liquidity traps, the denominator of the multiplier equation is lower than the numerator; thus, the output gap at the ZLB is larger than one. At the ZLB, with no cost channel, nominal interest rates remain unchanged, and an increase in government spending can generate inflation. Therefore, government spending leads to a drop in real interest rates, which, in turn, gives incentives to households to save less and consume more. This can be seen as the crowding effects as in Bouakez et al. (2017).

However, following positive spending shocks, the real cost channel can decrease short-run inflation through expectations of disinflation in firms’ real borrowing costs. Intuitively, lower marginal costs arise due to expected disinflation during liquidity trap episodes. Further, expectations of disinflation can translate into realized lower inflation rates through rational expectations and sticky prices. In this case, the real cost channel can make inflation rates rise by less than in the conventional model following positive spending shocks, and there is a smaller drop in real interest rates. Higher real interest rates due to the real cost channel can depress not only people’s appetite for consumption but also decrease production activity, which results in a decline in the effects of government spending on output. Hence compared to the standard NK model without the real cost channel, both the output gap multiplier and the inflation multiplier with the real cost channel are lower.

On the other hand, as explained in Section 2.1.1, the nominal cost channel cannot modify the NK Phillips Curve slope at the ZLB. Spending multipliers with this nominal cost channel can be invariant with the standard NK model since this channel in liquidity traps cannot be included in the partial derivative of government spending to the output gap/inflation in the calculation of fiscal multipliers.

I next discuss the effects of the strength of the real cost channel  $\gamma_r$  on spending multipliers. The stronger the power of the real cost channel, the lower inflation rates due to expectations of disinflation in liquidity traps. In this case, higher real interest rates due to lower inflation can depress people’s appetite for consumption, which results in more decline in the output gap multiplier. In a nutshell, both the inflation and the output gap multipliers with the real cost channel decrease in  $\gamma_r$ . I summarize the main theoretical results in Proposition 3.



**Proposition 3.** *At the ZLB, both the output gap multiplier  $\mathcal{M}_{S,Z}^O$  and the inflation multiplier  $\mathcal{M}_{S,Z}^I$  decrease in  $\gamma_r$ . The output gap multiplier relationship among the three models is*

$$\mathcal{M}_{S,Z}^O < \mathcal{M}_{S,Z}^{O,N} = \mathcal{M}_{S,Z}^{O,B}, \tag{20}$$

*and the inflation multiplier relationship is*

$$\mathcal{M}_{S,Z}^I < \mathcal{M}_{S,Z}^{I,N} = \mathcal{M}_{S,Z}^{I,B}, \tag{21}$$

*where in liquidity traps:  $\mathcal{M}_{S,Z}^{O,B}$  is the output gap multiplier without the cost channel and  $\mathcal{M}_{S,Z}^{O,N}$  is with the nominal cost channel;  $\mathcal{M}_{S,Z}^{I,B}$  is the inflation multiplier without the cost channel and  $\mathcal{M}_{S,Z}^{I,N}$  is with the nominal cost channel.*

*Proof.* See Online Appendix D. □

*Comparison with the literature.* Our study contrasts with that of Abo-Zaid (2022) who shows that higher borrowing costs with the nominal cost channel can increase inflation which makes the output gap multiplier larger than in the standard model at the ZLB. As in Abo-Zaid (2022), the Phillips Curve with the nominal cost channel at the ZLB is steeper in a  $(y_S, \pi_S)$  graph than in the standard NK model.<sup>22</sup> In this paper, I stress that inflation in the short run with the real cost channel can be lower due to expected disinflation in real borrowing costs.<sup>23</sup> Thus, I can use the real cost channel to explain lower spending multipliers in liquidity traps as in Ramey and Zubairy (2018).

*Taking stock of the denominator of the multiplier.* As discussed extensively in Bilbiie (2008), Mertens and Ravn (2014), Borađan Aruoba et al. (2018), and Nie and Roulleau-Pasdeloup (2023), the denominator of the multiplier in the standard NK model at the ZLB can be negative due to a highly persistent  $p$ .<sup>24</sup> In this case, the output gap and inflation multipliers are negative in equations (18)–(19).

However, as described at length in Nie (2021), in the presence of the real cost channel, the denominator with the ZLB binding is less likely to be negative than in the standard model.<sup>25</sup> I use the result from Nie (2021): The denominator can be always positive if assuming the elasticity of marginal costs w.r.t. the output gap  $\gamma_y$  is sufficiently small and meets the following condition:

$$\gamma_y < \Gamma(\gamma_r), \tag{22}$$

where  $\Gamma(\gamma_r) = \frac{(\beta - \kappa \gamma_r - 1 + \kappa \gamma_r \phi_\pi) \gamma_r \phi_\pi (\beta - \kappa \gamma_r)}{\sigma_r (1 - \kappa \gamma_r \phi_\pi)}$  increases in  $\gamma_r$ —See Online Appendix E.

As in condition (22),  $\gamma_y$  is lower than the composite parameter  $\Gamma(\gamma_r)$ , ensuring that the denominator is always positive. Assuming that  $\gamma_y$  is small enough for a given  $\gamma_r$ , this condition can always hold. In particular, the assumption with a low  $\gamma_y$  is in line with the empirical finding as in Beaudry et al. (2022):  $\gamma_y$  is very small while the key parameter  $\gamma_r$  leveraging the strength of the real cost channel is much larger than  $\gamma_y$ .

Bearing this in mind, in the following numerical exercise, I will consider only the case in which the denominator of the spending multiplier is positive.

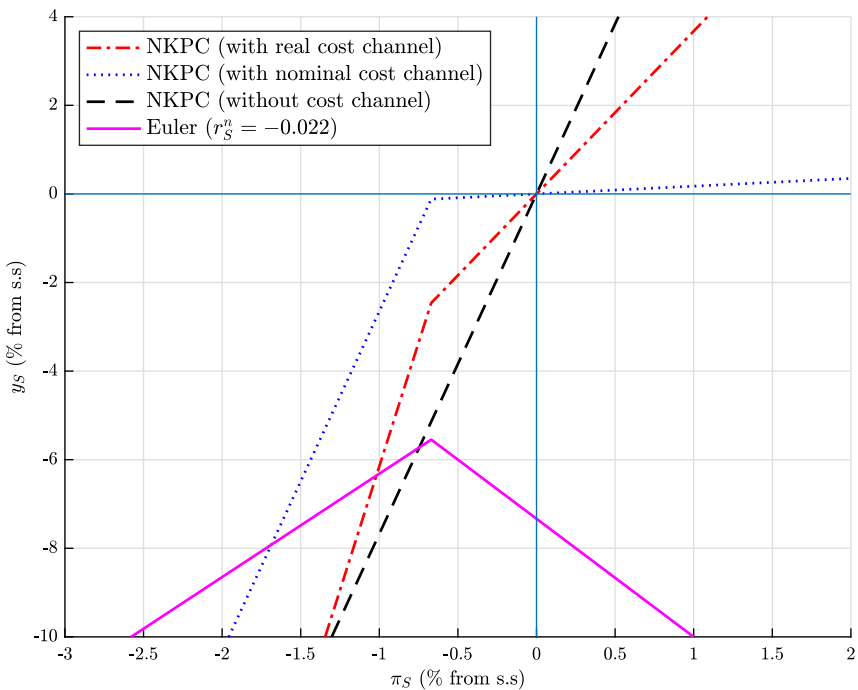
**2.4. Numerical results: benchmark**

In this paper, I follow Budianto et al. (2020), Roulleau-Pasdeloup (2021), and Beaudry et al. (2022) to set the parameterization reported in Table 1.<sup>26</sup>

I first provide numerical AS/AD figures with a contractionary natural rate shock in three NK Phillips Curves shown in Figure 1. The natural rate shock can move the Euler equation. If there is a temporary short-term natural rate shock  $r_S^n$  (−2.2%), which exceeds the boundary condition, the

**Table 1.** Parameterization

Subjective discount factor	$\beta = 0.99$
Inverse of Frisch elasticity	$\eta = 1$
Risk aversion coefficient	$\sigma_c = 1$
Steady-state ratio of government spending to output	$s_g = 0.2$
Elasticity of inflation w.r.t. real marginal cost	$\kappa = 0.2$
Elasticity of real marginal cost w.r.t. output gap	$\gamma_y = 0.2$
Elasticity of real marginal cost w.r.t. interest rate	$\gamma_r = 1$
Elasticity of real marginal cost w.r.t. government spending	$\gamma_g = -0.1$
Inflation parameter in Taylor rule	$\phi_\pi = \phi_\pi^q = 1.5$
Persistence specification	$\rho = 0.7$



**Figure 1.** AS/AD curves with natural rate shock in three models.

economy can be in liquidity traps.<sup>27</sup> In this case, the conventional monetary policy cannot work since the nominal interest rate is bounded at zero. Deflationary pressure can lead to higher real interest rates and further stimulate people to save but consume less. From Figure 1, it is clear that the real cost channel can change the Phillips Curve slope in liquidity traps and the Phillips Curve is locally flat as in Beaudry et al. (2022). The curve with the nominal cost channel at the ZLB shares the same slope as the conventional model. The numerical results also echo Proposition 1 that the case with the nominal cost channel is the most easily entrapped in liquidity traps among the three models.<sup>28</sup> This Proposition can be further confirmed in the impulse response to a contractionary natural rate shock—See Online Appendix F.

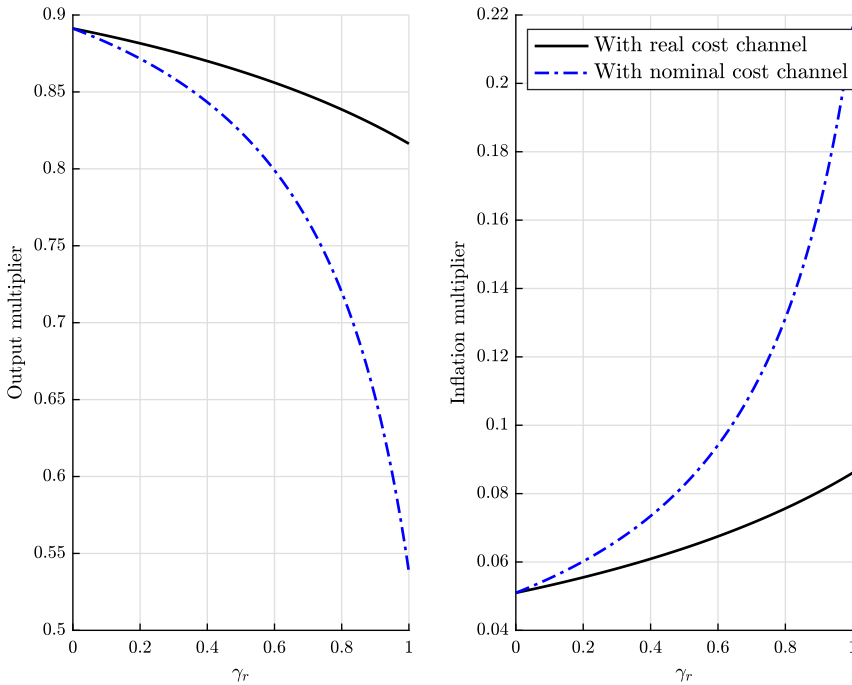


Figure 2. Spending multipliers in normal times.

I compare spending multipliers of the models in normal times without the cost channel ( $\gamma_r = 0$ ) vs. with the cost channel as in Ravenna and Walsh (2006) vs. with the real cost channel in Figure 2.<sup>29</sup> It can be seen that the output gap multiplier is lower than one as in Lewis (2021), and it decreases in  $\gamma_r$ . On the contrary, the inflation multiplier increases in  $\gamma_r$ . It is observed that the output gap multiplier with the real cost channel is larger than that with the nominal cost channel while less than its counterpart without the cost channel. This can echo the theoretical analysis in Proposition 2. See Online Appendix G for numerical results w.r.t. the persistence  $p$  in the three models. These numerical results robustly echo Proposition 2. I also find that the output gap multiplier decreases in  $p$ , whereas the inflation multiplier is higher with the duration of increment of time.

Figure 3 shows spending multipliers in liquidity traps. The simulation results can illustrate quantitatively our theoretical analysis in Proposition 3. On the one hand, one can see that the output gap multiplier is effective as in Christiano et al. (2011) and Schmidt (2017). The real cost channel can attenuate the output gap and inflation multipliers simultaneously. The spending multipliers decrease in  $\gamma_r$ . The nominal cost channel multipliers are invariant with the standard NK model without the cost channel.<sup>30</sup> See Online Appendix G for numerical results w.r.t.  $p$  in the three models, and these results further confirm our theoretical analysis. In addition, the output gap and inflation multipliers increase in  $p$ .

### 3. Government spending: long-run policy

As in recent contributions by Sarin et al. (2021) and Roulleau-Pasdeloup (2021), long-run policy effects are usually overlooked or often even computed numerically in the literature. In this section, I follow Roulleau-Pasdeloup (2023) to use a three-state Markov chain to assess long-run government spending analytically.

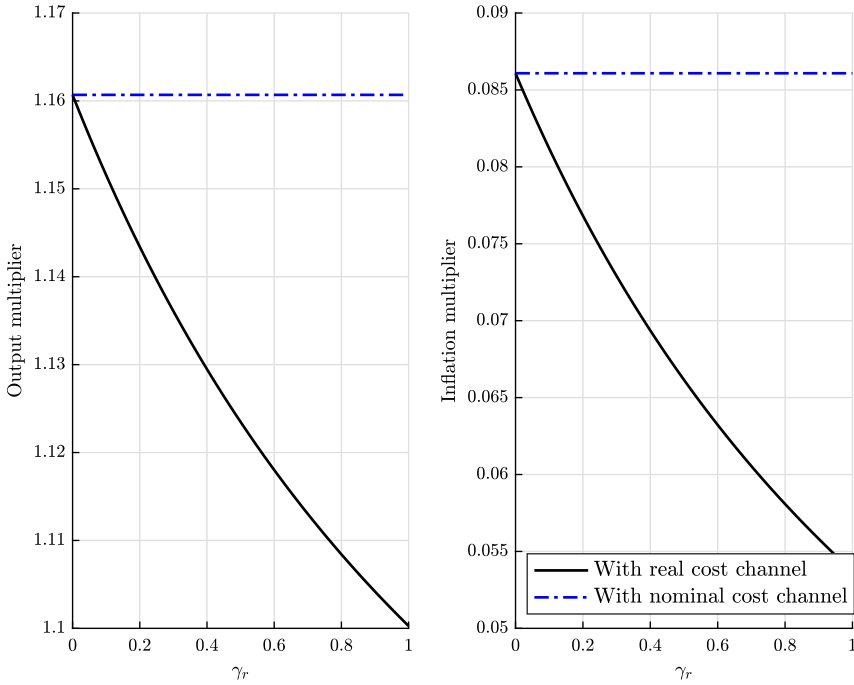


Figure 3. Spending multipliers at ZLB.

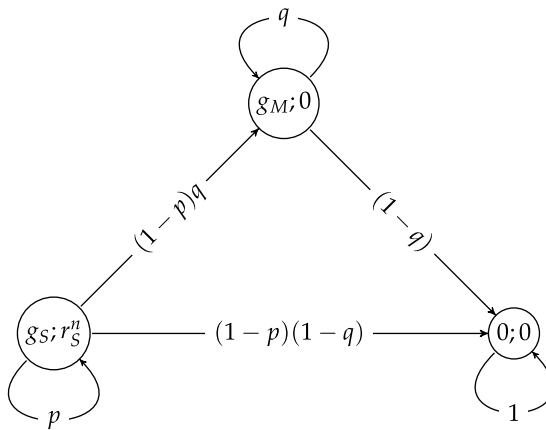


Figure 4. Long-run government spending: a graphical representation.

**3.1. Policy and shocks**

I assume that government spending is longer-lived than demand shock. To be more specific, government spending in the short run  $g_S$  can merge into medium-run government spending  $g_M$  with a persistence  $q$  and then collapse to the steady-state  $g_L = 0$  with a probability  $1 - q$ .<sup>31</sup> The natural rate shock  $r_S^n$  operates in the short run with a probability  $p$  and then returns to the long run  $r_L^n = 0$  with a probability  $1 - p$ . The graphical representation of our policy can be seen in Figure 4.

With this in mind, for current monetary policy, I use an adapted Taylor rule:<sup>32</sup>

$$R_t = \begin{cases} \max[0; -\log(\beta) + \phi_\pi \pi_S] & \text{In the short run} \\ -\log(\beta) + \phi_\pi^q \pi_M & \text{In the medium run} \\ -\log(\beta) & \text{In the long run} \end{cases} \quad (23)$$

One can use the above equation (23) to trace the path of government spending. In the medium run, the output gap and inflation can be expressed as the product of medium-run multipliers and medium-run government spending as follows:

$$y_M = \mathcal{M}_M^O \cdot g_M \quad \pi_M = \mathcal{M}_M^I \cdot g_M, \quad (24)$$

where  $\mathcal{M}_M^O$  is the medium-run output gap multiplier and  $\mathcal{M}_M^I$  is the medium-run inflation multiplier. See Online Appendix I for the medium-run spending multipliers.<sup>33</sup> In this case, since the model is forward-looking, I can generate the expected output gap below, and one can show the expected inflation using the same manner.

$$\begin{aligned} \mathbb{E}_S y_{t+1} &= p y_S + (1-p) q y_M \\ &= p y_S + (1-p) q \mathcal{M}_M^O g_M \\ &= p y_S + (1-p) q \mathcal{M}_M^O \zeta g_S. \end{aligned} \quad (25)$$

**3.2. Long-run government spending: theoretical analysis**

This section discusses the analytical results regarding the government spending multiplier with a three-state Markov structure.

*3.2.1. Multipliers with long-run government spending in normal times*

In normal times, one can use the Euler equation and the Phillips Curve in Online Appendix J to compute the output gap multiplier  $\mathcal{M}_{S,N}^{O,long}$  and the inflation multiplier  $\mathcal{M}_{S,N}^{I,long}$ :

$$\mathcal{M}_{S,N}^{O,long} = \frac{\Theta_{AD} \sigma (1-p) [1 - \beta p - \kappa \gamma_r (\phi_\pi - p)] - \Theta_{AS} (\phi_\pi - p)}{\sigma (1-p) [1 - \beta p - \kappa \gamma_r (\phi_\pi - p)] + \kappa \gamma_y (\phi_\pi - p)} \quad (26)$$

$$\mathcal{M}_{S,N}^{I,long} = \frac{(\kappa \gamma_y \Theta_{AD} + \Theta_{AS}) \sigma (1-p)}{\sigma (1-p) [1 - \beta p - \kappa \gamma_r (\phi_\pi - p)] + \kappa \gamma_y (\phi_\pi - p)}. \quad (27)$$

Long-run government spending can increase short-run inflation through rational expectations and sticky prices. In normal times, the central bank increases nominal interest rates to combat higher prices caused by inflation. In that way, long-run spending policy can crowd out more private consumption due to higher short-run real interest rates. Additionally, the real cost channel can increase marginal costs and inflation. Thus, the inflation multiplier can increase depending on the strength of the real cost channel  $\gamma_r$ , and this result is the same as the case in Section 2. Similarly, the real cost channel can lower the output gap. In summary, the output gap multiplier reduces in  $\gamma_r$  whereas the inflation multiplier grows in  $\gamma_r$ —For a formal proof, see Online Appendix K.

*3.2.2. Multipliers with long-run government spending at ZLB*

At the ZLB, I use the Euler equation and the Phillips Curve in Online Appendix J to produce the output gap multiplier  $\mathcal{M}_{S,Z}^{O,long}$  and the inflation multiplier  $\mathcal{M}_{S,Z}^{I,long}$ :

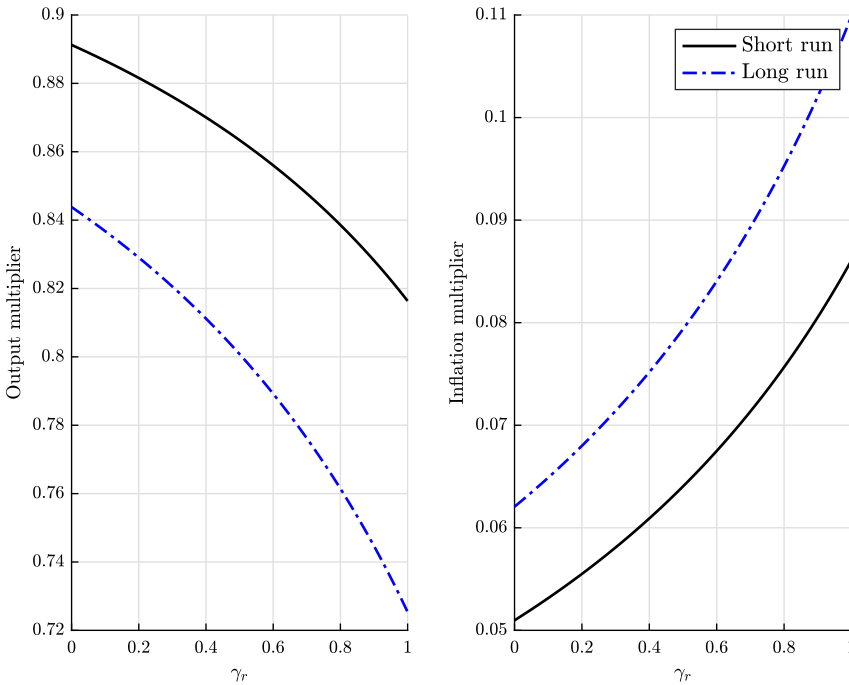


Figure 5. Spending multipliers with long-run spending policy in normal times.

$$\mathcal{M}_{S,Z}^{O, \text{long}} = \frac{\Theta_{AD}\sigma(1-p)(1-\beta p + \kappa\gamma_r p) + \Theta_{AS}p}{\sigma(1-p)(1-\beta p + \kappa\gamma_r p) - \kappa\gamma_r p} \tag{28}$$

$$\mathcal{M}_{S,Z}^{I, \text{long}} = \frac{(\kappa\gamma_r\Theta_{AD} + \Theta_{AS})\sigma(1-p)}{\sigma(1-p)(1-\beta p + \kappa\gamma_r p) - \kappa\gamma_r p}. \tag{29}$$

Once the liquidity trap has subsided, the extension of government spending policy can cause inflation to increase. The nominal interest rate is zero, and higher inflation can help stimulate our NK economy since it can lower short-run real interest rates and then increase private consumption. At this time, the spending multiplier is larger, which is in line with Bachmann and Sims (2012) who empirically show that long-term spending effects are larger than in the short-term policy model. However, the real cost channel can reduce the effectiveness of long-run government spending. The cost channel can dampen inflation due to expectations of disinflation in the real borrowing cost. Thus, the output gap and inflation multipliers decrease as the real cost channel becomes stronger—See Online Appendix L for an analytical analysis.

**3.3. Numerical results with long-run government spending**

The numerical results of short-run and long-run spending policies that vary with the strength of the real cost channel  $\gamma_r$  are presented in Figure 5.<sup>34</sup> In normal times, it is observed that long-run government spending can decrease the output gap multiplier. Moreover, long-run government spending can result in a larger inflation multiplier compared to short-run policies. The output gap multiplier falls in  $\gamma_r$  while the inflation multiplier increases in  $\gamma_r$ . See Online Appendix M for numerical results w.r.t. the persistence  $p$ . I find that the output gap multiplier can be negative with long-run spending.

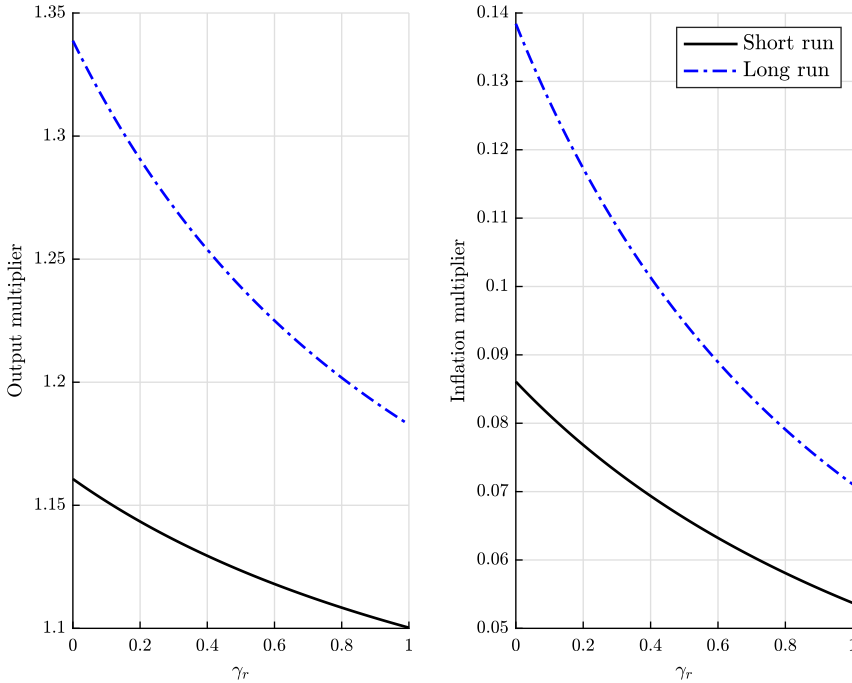


Figure 6. Spending multipliers with long-run spending policy at ZLB.

At the ZLB, the numerical results are reported in Figure 6. We find that long-run government spending can further increase the output gap and inflation multipliers. The two spending multipliers decrease in  $\gamma_r$ . Noteworthy is that the output gap multiplier can be more effective for a prolonged spending policy in recessions. Similar results can be found in Online Appendix M for numerical results w.r.t.  $p$ .

**4. A behavioral model**

As can be seen in Section 3, long-run government spending can drive spending multipliers at the ZLB. In our baseline model in Section 2, it is the consensus that agents have rational expectations. In this section, I extend the baseline model to address the role of rational expectations. I develop a model similar to Gabaix (2020) and incorporate it into our simple benchmark setup. This model considers bounded rationality, where agents can be short-sighted about the world.

**4.1. The NK model with Bounded Rationality**

I use the model in Gabaix (2020) to show the behavior of the aggregate demand-side economy:

$$c_t = \bar{m} \mathbb{E}_t c_{t+1} - \frac{1}{\sigma_c} (i_t - \mathbb{E}_t \pi_{t+1} - r^n), \tag{30}$$

where  $\bar{m} \in [0, 1]$  is the cognitive discounting parameter in Gabaix (2020).<sup>35</sup>

In this case, one can obtain the path of  $y_t$  by substituting the resource constraint into the Euler equation:

$$y_t = \bar{m}(1 - s_g) \mathbb{E}_t y_{t+1} - \frac{1}{\sigma} (R_t + \log(\beta) - \mathbb{E}_t \pi_{t+1} - r^n) + g_t - \bar{m}(1 - s_g) \mathbb{E}_t g_{t+1}, \tag{31}$$

where  $\sigma = \frac{\sigma_c}{1 - s_g}$ .

As in Gabaix (2020), I can derive the NK Phillips Curve with the real cost channel:

$$\pi_t = \beta \bar{m} \left[ \varphi + \frac{1 - \beta \varphi}{1 - \beta \varphi \bar{m}} (1 - \varphi) \right] \mathbb{E}_t \pi_{t+1} + \kappa \left[ \gamma_y y_t + \gamma_g g_t + \gamma_r (R_t + \log(\beta) - \mathbb{E}_t \pi_{t+1}) \right], \quad (32)$$

where  $\varphi \in (0, 1)$  is the share of firms that cannot adjust their prices.

**4.2. Government spending with bounded rationality: theoretical results**

This section presents the analytical results regarding government spending multipliers with bounded rationality.

*4.2.1. Multipliers with bounded rationality in normal times*

In normal times, I use the Euler equation and the Phillips Curve with the consideration of bounded rationality—see Online Appendix N, to produce the solutions of the output gap multiplier  $\mathcal{M}_{S,N}^{O,BR}$  and the inflation multiplier  $\mathcal{M}_{S,N}^{I,BR}$  below:<sup>36</sup>

$$\mathcal{M}_{S,N}^{O,BR} = \frac{\sigma [1 - p\bar{m}(1 - s_g)] \left\{ 1 - \beta p\bar{m} \left[ \varphi + \frac{1 - \beta \varphi}{1 - \beta \varphi \bar{m}} (1 - \varphi) \right] - \kappa \gamma_r (\phi_\pi - p) \right\} - \kappa \gamma_g (\phi_\pi - p)}{\sigma (1 - p\bar{m}(1 - s_g)) \left\{ 1 - \beta p\bar{m} \left[ \varphi + \frac{1 - \beta \varphi}{1 - \beta \varphi \bar{m}} (1 - \varphi) \right] - \kappa \gamma_r (\phi_\pi - p) \right\} + \kappa \gamma_y (\phi_\pi - p)} \quad (33)$$

$$\mathcal{M}_{S,N}^{I,BR} = \frac{\left[ 1 + \frac{\gamma_g}{\gamma_y} \right] \kappa \gamma_y \sigma [1 - p\bar{m}(1 - s_g)]}{\sigma [1 - p\bar{m}(1 - s_g)] \left\{ 1 - \beta p\bar{m} \left[ \varphi + \frac{1 - \beta \varphi}{1 - \beta \varphi \bar{m}} (1 - \varphi) \right] - \kappa \gamma_r (\phi_\pi - p) \right\} + \kappa \gamma_y (\phi_\pi - p)} \quad (34)$$

In normal times, cognitive discounting can reduce the expectation effects in our baseline model which can lower inflation following a positive spending shock. This means that there is a lower rise in real interest rates, hence a higher output gap multiplier compared to the baseline model. In this case, the inflation multiplier with bounded rationality can be lower, whereas the output gap multiplier can be higher<sup>37</sup>—see Online Appendix O for a formal proof. Since the introduced bounded rationality is independent of the strength of the real cost channel  $\gamma_r$ , the effects of this channel on spending multipliers are the same as the baseline model results. Specifically, the output gap multiplier decreases in  $\gamma_r$  while the inflation multiplier increases.

I find that the output gap multiplier can be large (near one) in normal times if we suppose agents have relatively intense bounded rationality which means the expectation effects are extremely weak. Intuitively, agents tend to consume today but not to save since future consumption has less or no effect on today’s decisions. In this case, the crowding-out effects of government spending should be much attenuated, and the output gap multiplier can be near one. This result echoes the previous empirical evidence that the output gap multiplier can be large in normal times as in Auerbach and Gorodnichenko (2012) and Acconcia et al. (2014).

*4.2.2. Multipliers with bounded rationality at ZLB*

At the ZLB, one can use the Euler equation and the Phillips Curve with bounded rationality—see Online Appendix N, to produce the output gap multiplier  $\mathcal{M}_{S,Z}^{O,BR}$  and the inflation multiplier  $\mathcal{M}_{S,Z}^{I,BR}$ :



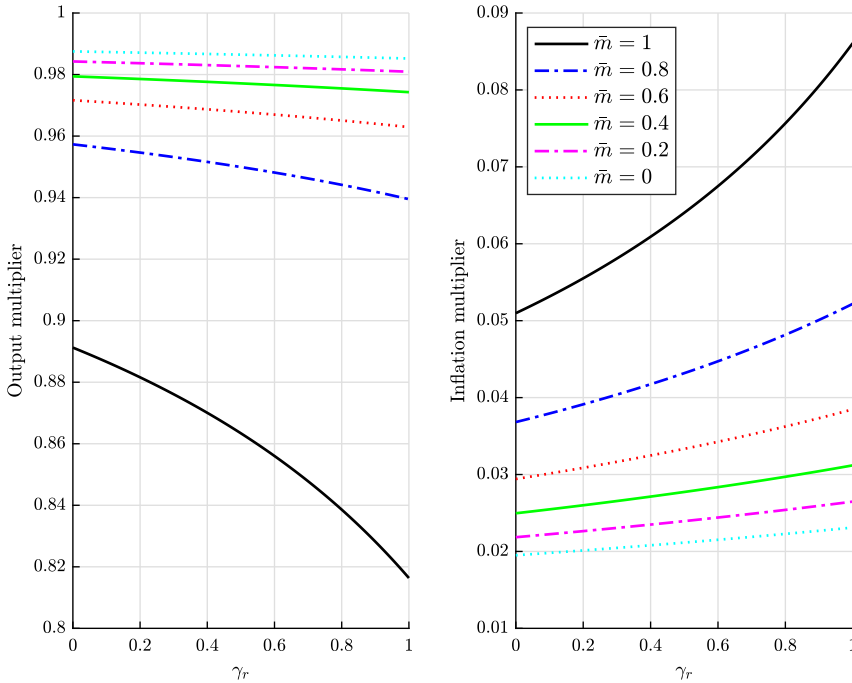


Figure 7. Spending multipliers with bounded rationality in normal times.

$$M_{S,Z}^{O,BR} = \frac{\sigma [1 - p\bar{m}(1 - s_g)] \left\{ 1 - \beta p\bar{m} \left[ \varphi + \frac{1 - \beta\varphi}{1 - \beta\varphi\bar{m}} (1 - \varphi) \right] + \kappa\gamma_r p \right\} + \kappa\gamma_g p}{\sigma [1 - p\bar{m}(1 - s_g)] \left\{ 1 - \beta p\bar{m} \left[ \varphi + \frac{1 - \beta\varphi}{1 - \beta\varphi\bar{m}} (1 - \varphi) \right] + \kappa\gamma_r p \right\} - \kappa\gamma_y p} \quad (35)$$

$$M_{S,Z}^{I,BR} = \frac{\left[ 1 + \frac{\gamma_g}{\gamma_y} \right] \kappa\gamma_y\sigma [1 - p\bar{m}(1 - s_g)]}{\sigma [1 - p\bar{m}(1 - s_g)] \left\{ 1 - \beta p\bar{m} \left[ \varphi + \frac{1 - \beta\varphi}{1 - \beta\varphi\bar{m}} (1 - \varphi) \right] + \kappa\gamma_r p \right\} - \kappa\gamma_y p} \quad (36)$$

At the ZLB, inflation caused by government spending can be lower due to cognitive discounting. Thus, it can increase real interest rates by less than in the standard model, which, in turn, can lower the output gap multiplier.<sup>38</sup> The effects on the strength of the real cost channel are the same as for the baseline model in liquidity traps. Specifically, the output gap and inflation multipliers decrease in  $\gamma_r$ —see Online Appendix P for a proof.

**4.3. Numerical results with bounded rationality**

Figure 7 shows how spending multipliers with bounded rationality vary with the value of  $\gamma_r$  for various values of  $\bar{m}$  in normal times. The main takeaway is that the output gap multiplier can be larger with a lower  $\bar{m}$  while the inflation multiplier can be lower under bounded rationality. In addition, the output gap multiplier decreases in  $\gamma_r$ , whereas the inflation multiplier increases in  $\gamma_r$ . See Online Appendix Q for numerical results w.r.t.  $p$ . I find that the output gap multiplier can decrease in  $p$  with rational expectations ( $\bar{m} = 1$ ) but increase in  $p$  with a small  $\bar{m}$ .

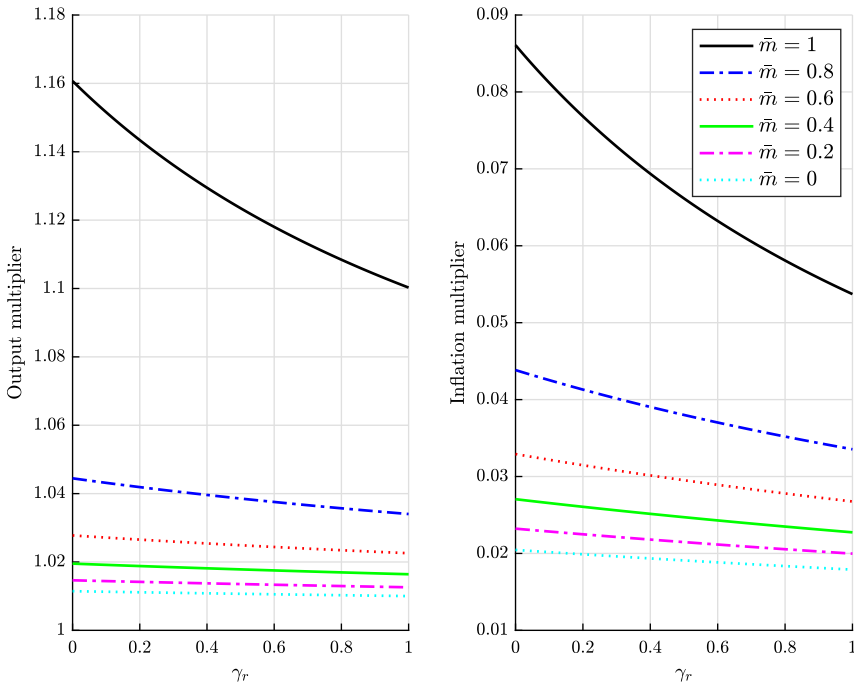


Figure 8. Spending multipliers with bounded rationality at ZLB.

The numerical simulation in Figure 8 shows that the inflation and output gap multipliers are lower with bounded rationality in liquidity traps. In addition, the role of the real cost channel with bounded rationality is the same as that of the baseline model. As in Online Appendix Q, the output gap multiplier increases numerically in  $p$ .

### 5. Concluding remarks

This paper considers the standard New Keynesian model with the real cost channel to explore government spending multipliers. The general properties of spending multipliers are identified using this analytical framework. During episodes of liquidity traps, it is found that the output gap multiplier with the real cost channel is smaller compared to the standard model without this channel, and it decreases as the strength of the real cost channel increases. I use this theoretical result to explain the lower government spending multiplier observed when nominal interest rates are fixed at the lower bound, consistent with empirical studies. The extent to which firms are subject to real borrowing costs can make government spending less effective in stimulating the economy in times of recession. In normal times, the output gap multiplier also decreases with this channel.

The robust role of the real cost channel on spending multipliers is confirmed. More specifically, our results on the role of the real cost channel, if one considers long-run government spending policy, are the same as for the short-run model. The benchmark model is also modified to include bounded rationality while retaining analytical tractability. Cognitive behavior can alter spending multipliers; however, the real cost channel still operates. This framework is sufficiently flexible that one can introduce heterogeneity along the lines of Bhandari et al. (2021), Cantore and Freund (2021), and Bayer et al. (2022) while retaining analytical tractability. I leave the analyses of other extensions to future work.

**Supplementary material.** To view supplementary material for this article, please visit <http://doi.org/10.1017/S1365100523000251>.

## Notes

- 1 See discussions on the fiscal tool to resist recessions as in Eggertsson (2011), Kollmann et al. (2012), Bouakez et al. (2020), and House et al. (2020).
- 2 See for example, Kiley (2014), Mertens and Ravn (2014) and Roulleau-Pasdeloup (2021).
- 3 There are a series of papers with the nominal cost channel specification which means that nominal interest rates are augmented in firms' marginal costs, such as Barth III and Ramey (2001), Ravenna and Walsh (2006), Llosa and Tuesta (2009), and Smith (2016).
- 4 Compared to the nominal cost channel, as explained at length in Beaudry et al. (2022), the real cost channel can be more empirically relevant to the US data. Furthermore, Nie (2021) formally proves that the real cost channel is theoretically appealing since it can ensure the equilibrium uniqueness/existence with temporary shocks.
- 5 In the calculation of fiscal multipliers, we need to gain the partial derivative of government spending to inflation/the output gap. If the introduced cost channel cannot change the NK Phillips Curve slope, the partial derivative should be the same as for the standard model.
- 6 There is a similar consideration with monetary policy. As in Nakata et al. (2019) and Budianto et al. (2020), the favorable effects of Forward Guidance—a promised long-run interest rate binding—on short-run inflation can be much attenuated if the economic agents cannot fully comprehend the world as represented by the NK model with rational expectations.
- 7 See Ramey (2011) for a survey on the estimation of government spending multipliers in the literature.
- 8 In this paper, we define the nominal cost channel as the cost channel of the nominal interest rate and the real cost channel as the cost channel of the expected real interest rate.
- 9 Following Christiano et al. (2011), I define  $g_t = (G_t - G)/Y$ .
- 10 The derivation of the NK Phillips Curve with the real cost channel can be seen in Online Appendix A.
- 11 See Online Appendix A for exact expressions of these parameters.
- 12 See Gertler et al. (1999) and Woodford (2003).
- 13 The subscripts '*S*' and '*L*' denote the state in the short and long run, respectively. The superscripts '*B*' and '*N*' denote the standard NK model without the cost channel and the model with the nominal cost channel, respectively. The duration of the short-run state can be calculated as  $T = \frac{1}{1-p}$ . For instance, if  $p = 0.5$ ,  $T = \frac{1}{1-0.5} = 2$  quarters.
- 14 In this paper, the three models refer to the conventional model without the cost channel, the model with the nominal cost channel, and the model with the real cost channel.
- 15 The superscripts '*O*' and '*I*' denote the output gap multiplier and the inflation multiplier, respectively. The subscript '*N*' denotes the economy in normal times.
- 16 Government spending in normal times can crowd out private consumption, echoing classical empirical evidence as in Amano and Wirjanto (1997) and Barro and Redlick (2011).
- 17 An increase in government spending requires households to produce more, leading to longer working hours. To compensate for this, households demand a higher real wage. This, in turn, increases firms' marginal costs, causing prices, which are set as a markup over the marginal cost, to also increase. This results in inflation.
- 18 This mechanism conforms with Ravenna and Walsh (2006) such that cost-push shocks can emerge endogenously in the NK model with the cost channel.
- 19 With Taylor (1993)-type rules followed by the central bank, there will be a rise in nominal interest rates by more than one-for-one with inflation pressure.
- 20 In this paper, the zero (effective) lower bound is a state when  $R_t = 0$  with the simple assumption that there are no cash storing costs in Galí (2015).
- 21 The subscript '*Z*' denotes that the economy is stuck at the ZLB.
- 22 Abo-Zaid (2022) differentiates between the policy rate and the loan rate, making the Phillips Curve steep in recessions. In that setup, if the two rates are equal, the nominal cost channel cannot impact the Phillips Curve slope in liquidity traps and cannot impact spending multipliers.
- 23 The Phillips Curve is locally flat with the real cost channel during recessions as in Beaudry et al. (2022). Besides, Hazell et al. (2020) empirically document that the NK Phillips Curve is flat during the Great Recession.
- 24 The denominator of the multiplier in the standard model is  $D_Z^B = \sigma(1-p)(1-\beta p) - \kappa\gamma_r p$  and can be negative with a large  $p$ .
- 25 The denominator of the multiplier with the real cost channel is  $D_Z = \sigma(1-p)(1-\beta p + \kappa\gamma_r p) - \kappa\gamma_r p$ , and one can show that  $D_Z = D_Z^B + \sigma(1-p)\kappa\gamma_r p$ . Therefore,  $D_Z$  is larger than  $D_Z^B$  and less likely to be negative—See Nie (2021) for details.
- 26 The calibration method for the real cost channel closely follows Beaudry et al. (2022). To be more specific, Beaudry et al. (2022) implicitly set  $\kappa = 1$  in their calibration. The calibration of the cost channel parameters,  $\kappa\gamma_r$  and  $\kappa\gamma_y$ , in this paper matches Beaudry et al. (2022). The elasticity of inflation w.r.t. real interest rates equals 0.2, as estimated in Beaudry et al. (2022). The other parameters are calibrated in a standard way as in Budianto et al. (2020) and Roulleau-Pasdeloup (2021).

In addition, the persistence  $p$  is set to ensure that the denominator of the multiplier remains positive, even in models without the cost channel.

27 This calibration mimics, for example, the case of the Great Recession.

28 Among the three models, the boundary condition for the natural rate shock with the nominal cost channel is the most restrictive, causing the economy to fall into liquidity traps.

29 For the purpose of illustration, the range of the parameter  $\gamma_r$  is from 0 to 1.

30 In Online Appendix H, the numerical result demonstrates a significant decrease in the output multiplier as we increase  $\gamma_r$  from 0 to 1 under the assumption that the persistence of government spending shocks is  $p = 0.8$ , exceeding the benchmark's  $p = 0.7$ .

31 The subscript ' $M$ ' means that the state is in the medium run.

32 In this section, to be in line with Section 2, I consider two economic states in the short run, which are normal times and the ZLB. In the medium run, I simply assume the demand shock reverts to zero and the economy is in normal times.

33 I follow a simple rule in Nie and Roulleau-Pasdeloup (2023) to deal with the medium-run shock: It is generally assumed that medium-run spending is contingent on short-run spending but it is lower than short-run spending such that  $g_M = \zeta g_s$ , where  $\zeta$  is a discount parameter.

34 In our simulation results, it is assumed that  $q = 0.7$  and  $\zeta = 0.5$ .

35 As in Gabaix (2020), this parameter can measure the attention to the future, which is a form of global cognitive discounting. Relative to rational expectations ( $\bar{m} = 1$ ), when the behavioral agents contemplate future events, their expectations are geared to the steady state of the economy.

36 For simplicity, in this section, a simple two-state Markov chain is used to calculate fiscal multipliers.

37 Similar results can also arise with long-run government spending since the cognitive agent can decrease the expectation effects, which is in spirit with Nakata et al. (2019) and Farhi and Werning (2019).

38 At the ZLB, bounded rationality weakens the multiplier, echoing the dampening effects of myopia, as shown in McKay et al. (2016) and Angeletos and Lian (2018).

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