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SHOULD THE FISCAL AUTHORITY AVOID IMPLEMENTATION LAG?

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Should the fiscal authority avoid implementation lag?*

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Abstract

Implementation lags are one of policymakers' concerns about fiscal policies, as these may reduce their efficacy. Using a standard New Keynesian model with an effective lower bound on the nominal interest rate, we compare the impacts of fiscal stimulus on output across various lengths of implementation lag. We show that despite concerns among policymakers, a fiscal authority can enhance the efficacy of government purchases on output with implementation lags when the economy is caught in a liquidity trap.

JEL Classification: E32; E52; E62

Keywords: Fiscal multiplier, Effective lower bound, Government spending, Liquidity trap

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1 Introduction

A broad consensus on discretionary fiscal policies is that they require long lags to implement. Following seminal work by Friedman (1953), it has been argued that fiscal policies with implementation lags may be ineffective or even destabilize the economy. While the argument has become less pessimistic, implementation lags in discretionary fiscal policies remain a concern in mitigating recession. For example, while Blanchard et al. (2009) argued for fiscal stimulus during the 2008–09 financial crisis, they also recognized the long implementation lags of fiscal policies as a risk. Their justification for fiscal stimulus with implementation lags relies on the fact that a financial crisis in practice lasts for many quarters. Christiano, Eichenbaum, and Rebelo (2011) also regard the long implementation lags as a risk. They find that the efficacy of fiscal policies depends on the state of the economy in which they are implemented. In particular, the effect of a fiscal stimulus on output is large when the effective lower bound (ELB) on the nominal interest rate is binding but becomes smaller when the ELB is not binding. Their finding implies that the fiscal multiplier is small if the government implements fiscal policy in some future period in which the ELB is no longer binding. Therefore, their analysis supports the conventional view that the fiscal authority should avoid implementation lag.

This note shows that a fiscal authority may not need to avoid implementation lags. Using the standard New Keynesian model with an ELB, we examine the efficacy of fiscal policy over various lengths of implementation lags. We find that implementation lags could enhance the efficacy of fiscal stimulus when the ELB is binding. Thus, a certain length of implementation lag may be desirable for the efficacy of fiscal stimulus. We also note, as Christiano, Eichenbaum, and Rebelo (2011) argued, that policymaker concerns remain valid when the ELB is no longer binding or when the economy has already recovered. That is, implementation lags in fiscal stimulus deteriorate the efficacy of fiscal stimulus on output when the nominal interest rate is positive. In such normal times, the fiscal authority should avoid implementation lags. Consequently, the desirability of implementation lags critically depends on whether the ELB is binding.

2 The model

The model we consider here is a standard closed-economy New Keynesian model with an ELB. The model shares various features discussed in Galí (2015), consisting of the consumption Euler equation, the New Keynesian Phillips curve (NKPC), and the Taylor rule with the ELB. Here we explicitly introduce fiscal policy with implementation lags into this standard model. For simplicity, we consider the deterministic version of the model because we focus only on the impulse response functions to the steady state. In what follows, we describe the key linearized equations of the model and leave the details to the appendix.

The consumption Euler equation in the representative agent model is given by

$$c_t = c_{t+1} - (r_t - \pi_{t+1} - \varrho_t)\,, \tag{1}$$

where c_t denotes the log-deviation of consumption from the steady state, r_t is the deviation of the net nominal interest rate from the steady state, and π_t is inflation. Here we assume zero inflation in the steady state and that the intertemporal elasticity of substitution is one. Following Krugman (1998), Eggertsson and Woodford (2003), and Jung, Teranishi, and Watanabe (2005), we introduce a deterministic preference "shock" ϱ_t into the consumption Euler equation to generate a liquidity trap in which the nominal interest rate hits the ELB.

The NKPC takes the following form:

$$\pi_t = \kappa\left(c_t + \frac{\alpha + \psi}{1-\alpha} y_t\right) + \beta\pi_{t+1}, \tag{2}$$

where y_t is the log-deviation of output from the steady state, $\psi > 0$ denotes (the inverse of) the Frisch elasticity of labor supply, and $\beta \in (0, 1)$ is the subjective discount factor of households. We assume the firm's production function with decreasing returns in labor, where $1-\alpha$ is the returns to labor.[1] Also, $\kappa \equiv [(1-\theta)(1-\beta\theta)/\theta)][(1-\alpha)/(1-\alpha+\varepsilon\alpha)]$ represents the slope of the NKPC, where θ is the probability that firms cannot reset their prices in each period and ε is the elasticity of substitution across differentiated goods. In (2), $c_t + [(\alpha+\psi)/(1-\alpha)]y_t$ represents the log-deviation of the average real marginal cost.[2]

The monetary authority sets the nominal interest rate according to a simple Taylor rule where r_t responds only to inflation: $r_t = \alpha_\pi \pi_t$ with $\alpha_\pi > 1$. Together with the ELB, the nominal interest rate is given by

$$r_t = \max\left(\alpha_\pi \pi_t, \ln\beta\right). \tag{3}$$

Recall that r_t is the deviation of the nominal interest rate. The steady-state nominal interest rate equals $\ln(1/\beta)$. Thus, the nominal interest rate becomes zero if and only if r_t decreases to $-\ln(1/\beta) = \ln\beta$.

We are interested in the impact of a fiscal policy shock on the economy. Following Galí, López-Salido, and Vallés (2007) and Galí (2020), denote g_t as the deviation of government purchases from the steady-state value expressed as a fraction of steady-state output (i.e., $g_t = (G_t - G)/Y$ where G_t, G, and Y are government purchases in period t, steady-state government purchases, and steady-state output, respectively).

The goods market satisfies the following market-clearing condition:

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

where γ is the steady-state government purchases to output ratio G/Y. As discussed in the next section, g_t is exogenously determined.

[1]Following Galí (2015), we assume that intermediate good producers produce differentiated goods using the production function $Y_t(i) = N_t(i)^{1-\alpha}$, where $Y_t(i)$ and $N_t(i)$ are the output of firm i and labor demand for firm i, respectively.

[2]Here, $c_t + \psi/(1-\alpha)y_t$ is the log-deviation of real wages expressed by the marginal rate of substitution between consumption and labor, and $\alpha/(1-\alpha)y_t$ is the log-deviation of aggregate labor productivity.

3 Policy experiments of implementation lags

3.1 Simulations

Our simulations aim to compare the effect of government purchases on output across various lengths of implementation lag. In simulations, the government makes an announcement at $t = 0$ that government purchases are to increase by one percent of steady-state output relative to steady-state government purchases. The increase in government purchases takes place in period $h \geq 0$ where h represents the length of the implementation lag. Government purchases g_t take the following values:

$$g_t = \begin{cases} 0 & \text{for } t < h, \\ \delta^{t-h} g_h & \text{for } t \geq h, \end{cases} \tag{5}$$

where $\delta \in [0, 1)$ measures the persistence of g_t because $g_{t+1} = \delta g_t$ for $t > h$. Throughout this paper, we consider fiscal stimulus, meaning that the government purchases in period h are always positive: $g_h > 0$.

We measure the overall effect of fiscal stimulus with implementation lag h on output by

$$\varphi_h = \frac{\sum_{t=0}^{\infty} \beta^t (Y_t - Y_t^R)}{\sum_{t=h}^{\infty} \beta^t (G_t - G)}. \tag{6}$$

The numerator represents the cumulative changes in output from its reference level Y_t^R, which we define later. It measures changes in output from the period of announcement ($t = 0$). The denominator is the cumulative changes in government purchases relative to the steady state. This measures changes in government purchases from the period of implementation ($t = h$). Both the numerator and the denominator are expressed as the present value.[3] As a function of h, we assess the overall effect of fiscal stimulus on output.

Note that φ_h shown in (6) includes the output responses from the periods of announce-

[3] We approximate (6) by $\sum_{t=0}^{60} \beta^t (Y_t - Y_t^R) / [\sum_{t=h}^{60} \beta^t (G_h - G)]$.

ment (i.e., from period 0 to $h-1$) as well as from the periods after implementation (i.e., from period h to ∞). Our measure looks like, but differs from, the net present value fiscal multiplier discussed in Uhlig (2010). The net present value fiscal multiplier is given by $[\sum_{t=0}^{s}\beta^t(Y_t - Y)]/[\sum_{t=0}^{s}\beta^t(G_t - G)]$, where s is the horizon for the fiscal multiplier and the reference level of output is $Y_t^R = Y$. This net present value fiscal multiplier is designed to measure how the cumulative effect of an unanticipated shock to government purchases varies with the increase in horizon. By contrast, φ_h fixes the horizon at infinity and evaluates how the cumulative effect of an anticipated shock to government purchases varies as the implementation lag increases.

As we proceed, it is useful to specify Y_t^R in (6) for our two experiments. The first experiment investigates the impact of government purchases on the economy in a normal time in which the ELB is not binding. In particular, we assume that $\varrho_t = 0$ for all $t \geq 0$, and thus the economy is initially in the steady state where the nominal interest rate is greater than zero (i.e., $r_t > \ln\beta$). In this sense, the economy is in the normal time. Because the initial state of the economy is in the steady state, this experiment specifies the reference level of output as $Y_t^R = Y$ for all t.

The next experiment considers the economy under a liquidity trap in which the nominal interest rate temporarily hits the ELB. In particular, we assume that a negative preference shock occurs in period 0 unexpectedly and continues to be negative for the next three years. After three years, the negative shock disappears. In equation $\varrho_t \simeq -0.003$ for $t = 0, 1, 2, ..., 11$ and $\varrho_t = 0$ for $t \geq 12$. We parameterize the size of the preference shock to ensure that the weakened aggregate demand temporarily generates the liquidity trap.[4] Because the ELB prevents the nominal interest rate from falling below zero, the recession caused by the preference shock is deeper in the case with the ELB than in that without the ELB. In response to the declines in aggregate demand, the government announces the fiscal stimulus in period 0 (the period when the negative preference shock hits the economy) and implements

[4]The parameterization for Figure 4 with this size of ϱ_t leads to a decline in output by five percent and a liquidity trap that lasts for eight quarters.

its policy in period h. We define the reference level of output Y_t^R in the second experiment as the equilibrium output where the preference shock disturbs the economy without fiscal stimulus. More specifically, Y_t^R is the equilibrium output arising from fluctuations in ϱ_t while keeping G_t at G for all t.

The remaining parameterization for the simulations is standard. We set β at 0.995, which implies a steady-state annualized real interest rate of two percent under zero steady-state inflation. The elasticity of substitution across differentiated goods ε is set to nine. The Frisch elasticity of labor supply is 1/5 so that $\psi = 5$ and the returns to labor in the production function $1 - \alpha$ is 3/4. In addition, we set θ such that the average duration of price changes is four quarters (i.e., $\theta = 3/4$). Following Galí, López-Salido, and Vallés (2007), we set γ at 0.2. The persistence of government spending δ is set to 0.5. Finally, $\alpha_\pi = 1.01$. Later, we confirm the robustness of our results to the coefficient on inflation in the Taylor rule.

3.2 Results

3.2.1 Experiment I: The economy in normal times

Figure 1 plots φ_h against h to compare the overall effect of the fiscal stimulus on output across various lengths of the implementation lag h. In this experiment, the initial state of the economy is the steady state in which $r_t > \ln \beta$.[5] Thus, the ELB is not binding when the government announces its fiscal stimulus.

[Figure 1 about here.]

The figure shows that implementation lags are not desirable in terms of the overall effect of a fiscal stimulus on output because the curve for φ_h decreases with h. This result suggests that fiscal stimulus without implementation lags performs best in terms of the overall effect on output. One important message in the first experiment is that the fiscal authority should avoid any implementation lags when the economy is in normal times. Quantitatively, the

[5]The definitions of $y_t \simeq (Y_t - Y)/Y$ and $g_t \simeq (G_t - G)/Y$ imply that $\varphi_h = \sum_{t=0}^{\infty} \beta^t y_t / \sum_{t=h}^{\infty} \beta^t g_t$.

decrease in efficacy is nonnegligible in that if a policymaker postpones the implementation of government purchases by one year after the announcement, the efficacy of the fiscal stimulus falls by almost 35 percent from $\varphi_0 = 0.81$ to $\varphi_4 = 0.53$.

The intuition is straightforward from (1). Government purchases with an h-period implementation lag raise the real interest rate in period h. An increase in the real interest rate decreases consumption in the same period ($c_h < 0$). Put differently, government purchases g_h crowd out consumption c_h as in the standard New Keynesian model. The decline in c_h is directly transmitted to the decline in the previous period c_{h-1} because of the forward-looking property of the consumption Euler equation (1), $c_{h-1} = c_h - (r_{h-1} - \pi_h)$. Furthermore, the reduction in consumption can be repeated backwards: the decline in c_{h-1} is directly transmitted to the decline in the previous period c_{h-2}. The reduction in c_t is then repeated if $0 \leq t \leq h$. If the real interest rate during $t \in [0, h)$ were constant, we would have $c_h = c_{h-1} = ... = c_0 < 0$. As the implementation lag lengthens, consumption has more opportunities to decline before the implementation of fiscal stimulus. Thus, a long implementation lag weakens the overall effect of the fiscal stimulus on output.[6]

3.2.2 Experiment II: The economy in a liquidity trap

We next turn to the second experiment. Figure 2 plots φ_h against h to compare the overall effect of the fiscal stimulus on output across various lengths of the implementation lag h. In contrast to the first experiment, the second experiment assumes that the preference shock $\varrho_t < 0$ lasts for three years and then returns to zero.[7]

[Figure 2 about here.]

[6] In simulations, the real interest rate between period 0 and $h-1$ is slightly lower than the steady-state value because a reduction in consumption causes inflation to decline, which in turn, lowers the nominal interest rate according to the Taylor rule $r_t = \alpha_\pi \pi_t$. As a result, $c_h < c_{h-1} < ... < c_0$ holds under our parameterization. Numerically, the effect of the future consumption dominates that of the real interest rate on c_t in (1). Therefore, equilibrium consumption declines before the implementation of the fiscal stimulus (i.e., $c_t < 0$ for $0 \leq t \leq h$) as discussed in the main text.

[7] Note that φ_h in this experiment reduces to $\varphi_h = \sum_{t=0}^{\infty} \beta^t (y_t - y_t^R)/[\sum_{t=h}^{\infty} \beta^t g_t]$, where y_t^R denotes the log-deviation of Y_t^R from the steady state Y.

In contrast to the result of the first experiment, the figure suggests that a certain length of implementation lag is desirable. In the second experiment, φ_h exhibits a hump shape that peaks at $h = 5$. This shape suggests that a fiscal stimulus with no implementation lag does not necessarily perform best in terms of the efficacy of the fiscal stimulus on output. Furthermore, the increment in efficacy is substantial, such that if a policymaker postpones the fiscal stimulus by five quarters after the announcement, the efficacy of the fiscal stimulus will approximately triple from $\varphi_0 = 1.26$ to $\varphi_5 = 3.90$. An important message in the second experiment is that the fiscal authority does not always need to avoid implementation lag when the ELB is binding.

We emphasize that the main result from this experiment is robust to changes in the parameters. Among others, the coefficient on inflation in the Taylor rule may influence our results because α_π directly affects aggregate demand through the nominal interest rate r_t in the consumption Euler equation (1). Figure 3 indicates how φ_h changes across four values of $\alpha_\pi = \{1.01, 1.25, 1.50, 1.75\}$. In all cases, φ_h is hump-shaped against h. In particular, φ_h increases with h up to $h \leq 5$ and is maximized at $h = 5$, regardless of the value of α_π. Once h exceeds five, the overall effect of the fiscal stimulus on output declines over h and becomes more significant as α_π becomes larger.

[Figure 3 about here.]

Our finding on the desirability of implementation lags sharply contrasts with the broad consensus among policymakers. Since Friedman (1953), lags in implementing fiscal policies have long been a concern for policymakers. Even in recent studies, this concern remains, although it has become less irrelevant. For example, Blanchard et al. (2009) argue for fiscal stimulus during a financial crisis, but also recognize that implementation lags remain a risk for fiscal stimulus. Christiano, Eichenbaum, and Rebelo (2011) point out that while the fiscal multiplier is large under the liquidity trap, it is small when the nominal interest rate becomes positive. Their result means that the fiscal stimulus are effective especially when the ELB is binding. Our finding differs from these previous studies in pointing out the *desirability* of implementation lags when the ELB is binding.

3.3 Model dynamics of the economy in a liquidity trap

In this section, we explain the mechanism behind the hump shape in Figure 3, based on model responses to shocks. Figure 4 presents the model dynamics of output, consumption, the nominal interest rate, and the real interest rate in experiment II. These variables are shown in terms of the responses to an anticipated increase in government purchases. The nominal and real interest rates in the figure are multiplied by four to express them at an annual rate. We employ $\alpha_\pi = 1.5$ to detect significant differences in the model responses for different values of h. In each panel of Figure 4, the dashed line presents the responses of a variable arising from declines in ϱ_t while keeping G_t at G for all t. By definition, the dashed line corresponds to the model responses without government intervention (i.e., the reference level of a variable such as y_t^R). Here, negative preference shocks lasting for three years weaken aggregate demand such that the nominal interest rate hits the ELB. In particular, negative preference shocks cause output to decrease by five percent and the nominal interest rate to decline by two percent. However, the nominal interest rate cannot decrease below $\ln \beta$ because of the ELB. The ELB binds for two years during $0 \leq t \leq 7$. Given a decline in inflation from weakened aggregate demand, the real interest rate increases strongly when the nominal interest rate hits the ELB.

[Figure 4 about here.]

We are now ready to discuss the effect of a fiscal stimulus with implementation lag. Figure 4 selects two values for the implementation lags: $h = 4$ (the solid line with circles) and $h = 12$ (the solid line with diamonds). For reference, the vertical lines in each panel represent the period of implementation of the fiscal stimulus. Note that an implementation lag of one year means that the government implements the fiscal stimulus under a liquidity trap because

$r_t = \ln\beta$ for $0 \leq t \leq 7$ without government intervention. By contrast, an implementation lag of three years implies that the government implements the fiscal stimulus when the ELB is no longer binding. Recall that the overall effect of fiscal stimulus on output almost peaks in $h = 4$, but is considerably smaller when $h = 12$ (See Figure 3). In particular, under our calibration of $\alpha_\pi = 1.5$, $\varphi_4 = 3.30$ and $\varphi_{12} = -3.28$.[8]

Let us first discuss the effect of a fiscal stimulus on output when implemented under a liquidity trap ($h = 4$). The solid line with circles in Figure 4 details the model responses to both an increase in g_t and a decrease in ϱ_t. In the upper panel, the solid line with circles (y_t) is located uniformly above the dashed line (y_t^R), especially several quarters after the announcement of a fiscal stimulus in period 0. That is, government purchases with an implementation lag of one year raise output relative to the reference level. The positive effect on output is summarized by $\varphi_4 = 3.30$ in Figure 4.

To obtain the intuition behind the positive effect on output, define the *relative* consumption Euler equation as

$$\tilde{c}_t = \tilde{c}_{t+1} - \left(\tilde{r}_t - \tilde{\pi}_{t+1}\right), \tag{7}$$

where the variable with a tilde denotes the variable relative to the reference level. In particular, $\tilde{c}_t = c_t - c_t^R$ is consumption relative to its reference level. Analogously, we can define $\tilde{r}_t$ by $r_t - r_t^R$ and $\tilde{\pi}_t$ by $\pi_t - \pi_t^R$. Equation (7) compares two consumption Euler equations by taking the difference from the reference level. The preference shock ϱ_t disappears in (7) because ϱ_t is common to the two consumption Euler equations and they thus cancel each other out.

Government purchases with $h = 4$ increase inflation without affecting the nominal interest rate because the economy is caught in a liquidity trap (see the solid line with circles for $0 \leq t \leq 7$ in the lower-left panel). Higher inflation caused by the implementation of the fiscal stimulus then lowers the real interest rate relative to the reference level, as shown in

[8] We chose $\alpha_\pi = 1.5$ for Figure 4 because a large value of α_π enables us to compare the model responses more easily than would be the case with a low value of α_π (e.g., $\alpha_\pi = 1.01$).

the lower-right panel of Figure 4. This low real interest rate, in turn, stimulates consumption in the same period (see the upper-right panel in period $t = h$). Put differently, government purchases increase relative consumption because of the crowding-in effect of government purchases. In terms of (7), g_h leads to $\tilde{c}_{h-1} > 0$ through a lower real interest rate $\tilde{r}_{h-1} - \tilde{\pi}_h < 0$. This crowding-in effect is well known in the literature (Woodford (2011) and Christiano, Eichenbaum, and Rebelo (2011)).

The forward-looking property of the relative consumption Euler equation (7) creates the desirability of implementation lags. The increased consumption is directly transmitted to the increase in the previous period because $\tilde{c}_{h-2} = \tilde{c}_{h-1} - (\tilde{r}_{h-2} - \tilde{\pi}_{h-1})$. The increase in consumption can be repeated backwards to $\tilde{c}_{h-3}$ and $\tilde{c}_{h-4}(= \tilde{c}_0)$. If the real interest rate were constant, we would have $\tilde{c}_{h-1} = \tilde{c}_{h-2} = ... = \tilde{c}_0 > 0$. Households can enjoy more consumption (and output) from the time of the announcement of the fiscal stimulus rather than the time of its implementation. Thus, increases in consumption $\tilde{c}_t$ for $0 \leq t < h$ strengthen the overall effect of fiscal stimulus on output. As the implementation lag lengthens, consumption has more opportunities to increase before the implementation of the fiscal stimulus.[9]

We next turn to the case of $h = 12$ where the fiscal stimulus is implemented after a liquidity trap ($h = 12$). In contrast to the case of $h = 4$, the effect of the fiscal stimulus on output is negative. As shown by the solid line with diamonds in the upper panels of Figure 4, y_t and c_t are now located below y_t^R and c_t^R, respectively, in the period before the fiscal stimulus is implemented at $t = h = 12$. Thus, government purchases with an implementation lag of three years lower output relative to the reference level. The negative effect is reflected in $\varphi_{12} = -3.28$ in Figure 4.

When the fiscal stimulus is implemented after a liquidity trap, the implementation lag is no longer desirable. Not surprisingly, the intuition in experiment I is applicable to this result. The increase in g_h raises the real interest rate relative to the reference level, which creates

[9] Numerically, the real interest rate for $0 < t < h - 1$ is lower than the reference level (see the lower-right panel of Figure 4) given the high inflation caused by $\tilde{c}_t > 0$ for $1 < t < h$. The falls in the real interest rate over $0 < t < h - 1$ further stimulate consumption relative to the reference level. Thus, allowing for fluctuation in the real interest rate does not influence our interpretation.

the crowding-out effect, as the ELB is no longer binding in period $t = h = 12$. Because the forward-looking property is preserved in the relative consumption Euler equation (7), relative consumption begins decreasing relative to the reference level from the time of the announcement ($t = 0$). Once again, as the implementation lag becomes longer, consumption has more opportunities to decline before the implementation of the fiscal stimulus.[10] As a result, φ_h tends to decline with the implementation lag for $t \geq h$.

Before closing this section, two remarks are in order. First, using a New Keynesian model with a fixed nominal interest rate, Farhi and Werning (2016) analytically prove that consumption in the initial period (i.e., $\tilde{c}_0$ in our notation) is more strongly crowded in by government purchases the farther the distance in time of implementation. In our model, such a strong crowding-in effect does not occur. As shown by the solid lines with diamonds in Figure 4, relative consumption in the initial period $\tilde{c}_0$ is crowded out by government purchases. The reason is that the nominal interest rate is endogenous and no longer fixed when the economy has almost recovered.

Second, Ngo (2021) shows that the fiscal multiplier is not monotonic in the persistence of government purchases in the New Keynesian model with ELB. We can interpret his results from the viewpoint of implementation lag. In his model, if increases in government purchases become negligible after a liquidity trap, an increase in the persistence of government purchases increases the fiscal multiplier. By contrast, if increases in government purchases remain substantial even after a liquidity trap, an increase in the persistence of government purchases decreases the fiscal multiplier. In our model, the former corresponds to the case in which government purchases are implemented during a liquidity trap, and the latter corresponds to the case in which they are implemented after a liquidity trap.

[10] In simulations, the ELB is binding for $0 \leq t \leq 8$ and is not binding for $9 \leq t \leq 11$. In the former period, inflation relative to the reference level is low due to the weak aggregate demand and thus the real interest rate is high relative to the reference level. The higher real interest rate during the binding ELB further decreases $\tilde{c}_t$ and lowers the overall effect of fiscal stimulus on output.

4 Conclusion

Since Friedman (1953), lags in fiscal policies have been a concern of policymakers because they may reduce the efficacy of fiscal policies. Even recent studies support the conventional view that the fiscal authority should avoid implementation lag.

We showed that implementation lags could enhance the efficacy of fiscal stimulus on output when the ELB is binding. The efficacy exhibits a hump shape against the length of implementation lags, suggesting that the fiscal authority can improve efficacy by delaying the implementation of its fiscal stimulus. The desirability of implementation lags critically depends on whether the ELB is binding.

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A The model description

In this appendix, we describe the details of the model in Section 2.

Households A representative household maximizes its lifetime utility given by $\sum_{t=0}^{\infty}\beta^t U\left(C_t, N_t; Z_t\right)$, where $U\left(C_t, N_t; Z_t\right) = \left[\log C_t \; - N_t^{1+\psi}/\left(1+\psi\right)\right] Z_t$. Here, C_t, N_t, and Z_t represent consumption, labor supply, and an exogenous preference shifter, respectively. The parameter $\psi > 0$ denotes the inverse of the Frisch elasticity of labor supply and $0 < \beta < 1$ is the subjective discount factor of the household. The household faces a budget constraint:

$$B_t + P_t C_t = (1 + R_{t-1})B_{t-1} + W_t N_t + P_t D_t - P_t T_t, \tag{8}$$

where B_t denotes the household's nominal holdings of one-period government bonds paying a nominal interest rate R_t, P_t is the aggregate price index, and W_t is nominal wages. Furthermore, D_t denotes firms' real profits and T_t is lump-sum taxes in real terms. The household maximizes its lifetime utility subject to (8), yielding the following first-order conditions:

$$1 = \beta(1 + R_t)\frac{C_t}{C_{t+1}}\frac{Z_{t+1}}{Zt}\frac{P_t}{P_{t+1}}, \tag{9}$$

$$C_t N_t^{\psi} = \frac{W_t}{P_t}. \tag{10}$$

Log-linearizing (9) around the steady state gives (1). In deriving (1), we define the preference shock ϱ_t as $\varrho_t = -\ln(Z_{t+1}/Z_t)$.

Firms The representative firm produces the final good in a perfectly competitive market. It combines a continuum of intermediate goods, using the technology $Y_t = \left(\int_0^1 Y_t(i)^{(\varepsilon-1)/\varepsilon} di\right)^{\varepsilon/(\varepsilon-1)}$, where $Y_t(i)$ denotes output produced by the intermediate good producers $i \in [0, 1]$ and ε (> 1) is the elasticity of substitution among differentiated goods. The aggregate price index P_t is associated with intermediate good prices $P_t(i)$ by $P_t = \left(\int_0^1 P_t(i)^{1-\varepsilon} di\right)^{1/(1-\varepsilon)}$. The production function for intermediate good producers is $Y_t(i) = N_t(i)^{1-\alpha}$, where $\alpha \in (0, 1]$.Each intermediate good producer can reset its price with probability $1 - \theta$ in any given period. Let P_t^* be the optimal nominal price set by an intermediate good producer. The optimal nominal price solves the maximization problem:

$$\max_{P_t^*} \sum_{k=0}^{\infty} \theta^k Q_{t,\,t+k}(1/P_{t+k}) \left(P_t^* Y_{t+k|t} - W_{t+k} Y_{t+k|t}^{\frac{1}{1-\alpha}}\right),$$

subject to the demand function $Y_{t+k|t} = \left(P_t^*/P_{t+k}\right)^{-\varepsilon} Y_{t+k}$, where $Y_{t+k|t}$ denotes an intermediate good producer's output in period $t + k$ given that the producer last reset its price in period t and $Q_{t,t+k} \equiv \beta^k C_t / C_{t+k}$ is the discount factor. The first-order condition for P_t^* is

$$\sum_{k=0}^{\infty} \theta^k Q_{t,t+k} (1/P_{t+k}) Y_{t+k|t} \left(P_t^* - \frac{\varepsilon}{\varepsilon - 1} W_{t+k|t} Y_{t+k|t}^{\frac{\alpha}{1-\alpha}} \right) = 0. \tag{11}$$

Along with the equation for the price index, the log-linearization of the above equation yields the NKPC (2).

Market clearing Equilibrium in the final goods market requires $Y_t = C_t + G_t$. Using the definitions of $g_t = (G_t - G)/Y$, we obtain (4). The labor market clearing condition is $N_t = \int_0^1 N_t(i)\, di$ for all t.

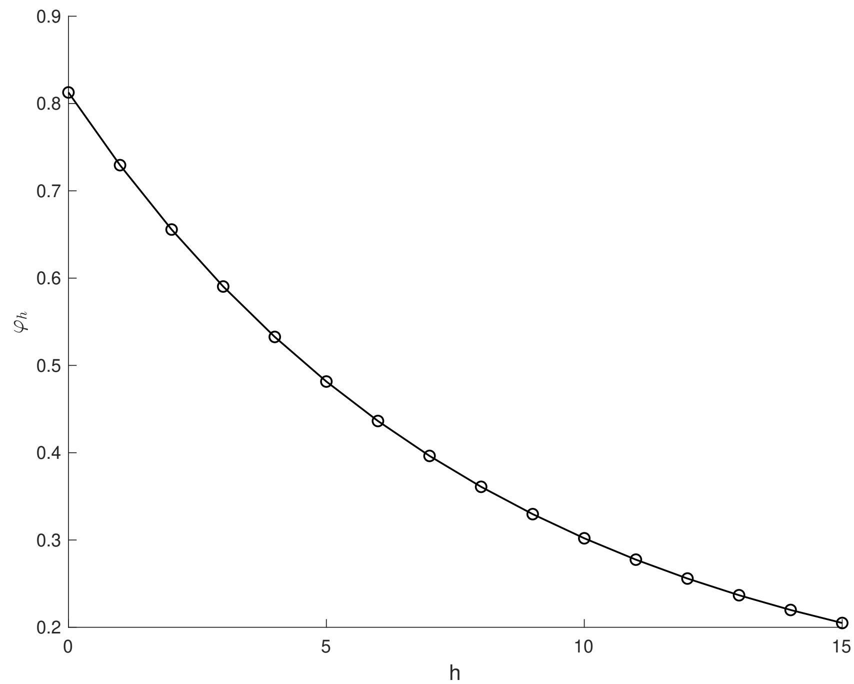

Figure 1: The overall effect of fiscal stimulus on output in normal times

Note: An increase in government purchases is announced in period 0 and implemented in period h. The increase in government purchases is normalized to one percent of the steady-state output. At the time of announcement, the economy is in the steady state. The unit of time is a quarter.

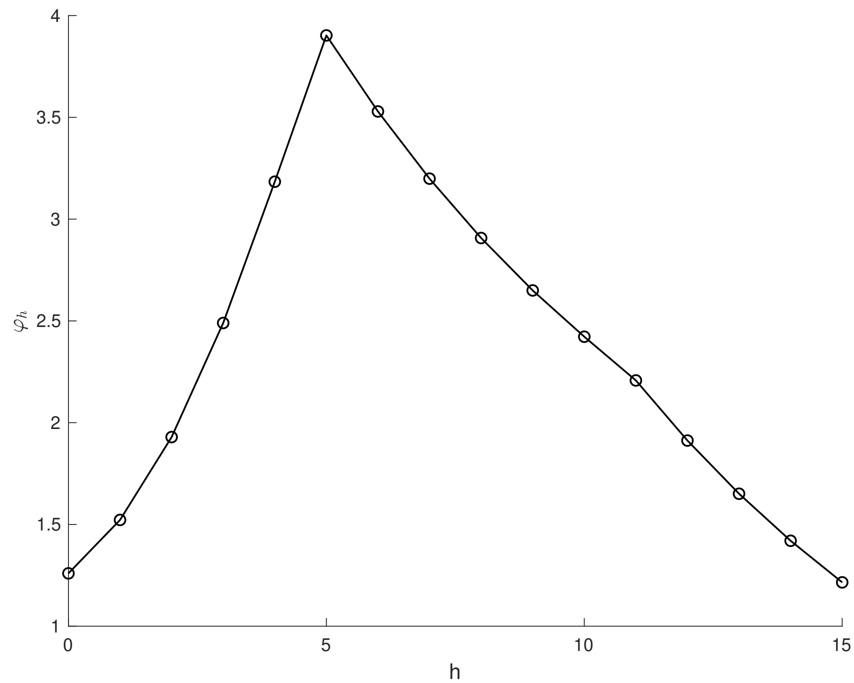

Figure 2: The overall effect of fiscal stimulus on output in a liquidity trap

Note: An increase in government purchases is announced in period 0 and implemented in period h. The increase in government purchases is normalized to one percent of the steady-state output. At the time of announcement, the economy is caught in a liquidity trap. The unit of time is a quarter.

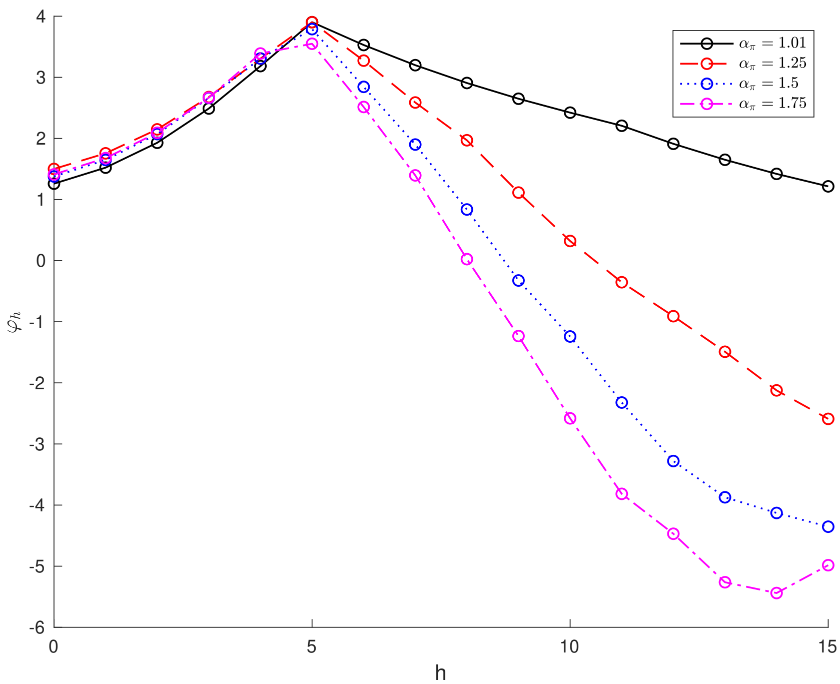

Figure 3: The overall effect of fiscal stimulus on output in a liquidity trap under different α_π

Note: The solid line replicates φ_h under $\alpha_\pi = 1.01$ in Figure 2 for comparisons. The dashed, dotted, and dash-dotted lines represent φ_h under $\alpha_\pi = 1.25$, 1.5, and 1.75, respectively. See the note accompanying Figure 2 for the remaining details.

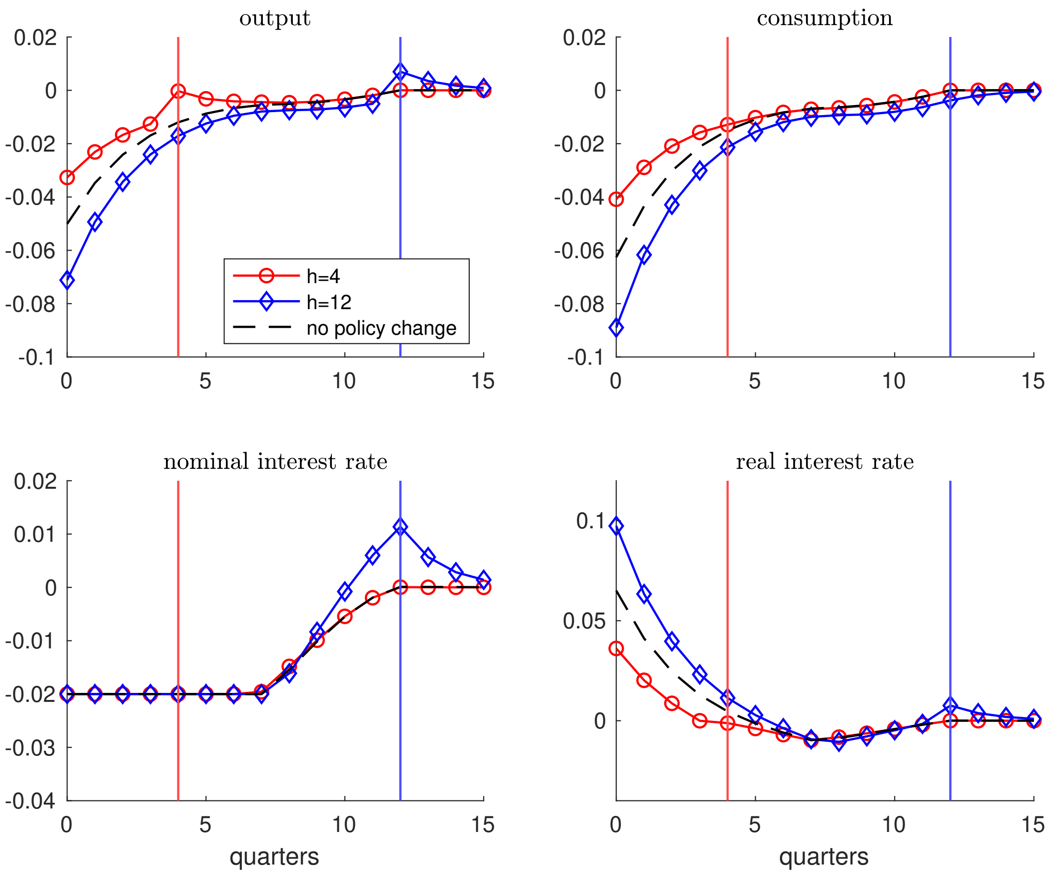

Figure 4: Responses of variables to changes in ϱ_t and g_t

Note: Each panel of the figure compares the model responses to ϱ_t and g_t for an implementation lag of between one and three years ($h = 4$ and $h = 12$), along with the reference level of the corresponding variables. The upper-left and the upper-right panels refer to output and consumption, respectively. The lower-left and the lower-right panels present the nominal interest rate and the real interest rate, respectively. The dashed line in each panel represents the equilibrium responses of a variable arising from fluctuations in ϱ_t while keeping G_t at G for all t (denoted by "no policy change"). The solid lines in each panel refer to the model response to decreases in the preference shock and increases in government purchases. The solid line with circles is the model responses under $h = 4$, and the solid line with diamonds is the model responses under $h = 12$. The horizontal axis is the quarters after the preference shocks. The vertical lines in each panel represent the timing of the implementation of the fiscal stimulus. In the figure, $\alpha_\pi = 1.5$ and $\varphi_h = 3.30$ at $h = 4$ and $\varphi_h = -3.28$ at $h = 12$.