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Does nominal wage stickiness affect fiscal multiplier in a two-agent new Keynesian model?*

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Abstract

This study examines the effect of nominal wage stickiness on the fiscal multiplier in a two-agent new Keynesian model. We demonstrate that in the case of sticky nominal wages, an increased share of liquidity-constrained (LC) consumers decreases the money-financed (MF) fiscal multiplier. Our model shows that the fiscal multiplier under an MF regime outperforms that under a debt-financed (DF) regime. Under empirically plausible calibration, the benchmark model indicates that the MF government-spending multiplier is 1.5–3.0, whereas the DF multiplier is 0.8–1.5. We also find that an increased share of LC consumers magnifies the tax-cut multiplier in the cases of MF and DF regimes despite nominal wage stickiness.

JEL codes: E52; E58;

Keywords: Money-financed regime; Debt-financed regime; Nominal wage stickiness; Liquidity-constrained consumers; Two-agent new Keynesian model

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1 Introduction

How can fiscal authorities enhance the effect of fiscal policy on the real economy? The basic concept of fiscal policy generally implies that future tax increases accompany fiscal stimulus through government spending or tax cuts. This standard fiscal stimulus is often labeled as debt-financed fiscal stimulus (DF). Such fiscal stimulus usually increases real interest rates, leading to a crowding-out effect that weakens the impact of fiscal stimulus on output. Alternatively, several studies have proposed money-financed (MF) fiscal stimulus, which is characterized by policy coordination between monetary and fiscal authorities. For instance, introducing large-scale fiscal stimulus and quantitative easing in the US may be an example of an MF regime.[1] Thus, the MF regime can be regarded as a policy instrument aimed at recovery from a deep recession. In other words, without coordination with monetary policy, it may be difficult to boost the economy through an accumulation of government spending. Several studies have argued the effectiveness of fiscal policy under an MF regime during the zero lower bound (ZLB) on nominal interest rates (Bernanke, 2003, Galí, 2020b). The nominal interest rate has increased in advanced and emerging countries, excluding the Japanese economy; however, it should be important to consider whether fiscal stimulus remains effective even when the ZLB is absent. In fact, the emerging countries that do not experience the ZLB argue the possibility of MF fiscal stimulus (Lindquist, Ilahi, and Lee, 2021). The above discussion inspired this paper.

An ancestor discussion of the MF fiscal stimulus can be linked to the idea proposed by Friedman (1969), who mentioned the possibility of this policy regime, often known as "helicopter money."[2] Bernanke (2003) specified the role of an MF fiscal stimulus as a potential tool for lifting the real economy when the nominal interest rate faces the ZLB floor. Moreover, a previous study has argued that the COVID-19 shock motivated consideration of the MF fiscal stimulus (Galí, 2020b). Reis and Tenreyro (2022) reviewed the related literature on the role of MF and DF fiscal stimulus, highlighting the possibility of its different meanings in the literature. Galí (2020a) investigated the effect of an MF fiscal stimulus in the standard new Keynesian (NK) model and argued that nominal price stickiness should be considered when evaluating the effect of fiscal stimulus through government spending or tax cuts. Punzo and

[1] The combination of the American Recovery and Reinvestment Act (ARRA) and the Federal Reserve Board's quantitative easing policy in the US can be considered an example of an MF regime.

[2] See also Turner (2015) for a detailed discussion about MF fiscal regimes.

Rossi (2022) examined the effect of household heterogeneity on the MF fiscal stimulus in an NK model. However, the abovementioned studies did not explore the role of nominal wage stickiness despite the importance addressed in several studies on NK models (Ascari, Colciago, and Rossi, 2017, Erceg, Henderson, and Levin, 2000, Galí, 2013, Galí and Monacelli, 2016). Naturally, these arguments also motivate our research question of whether its regime is significantly affected by the interaction between nominal wage stickiness and household heterogeneity.

To address our research question, we examine the effect of nominal wage stickiness on the fiscal multiplier in a two-agent new Keynesian (TANK) model. There are two reasons why we construct this model. First, as mentioned earlier, several studies have confirmed the importance of nominal wage stickiness in an NK model.[3] For instance, Broer, Krusell, and Öberg (2023) examined the effect of nominal wage stickiness on the fiscal multiplier in a heterogeneous agent NK (HANK) model. They argued the effect of nominal wage stickiness on the fiscal multiplier under a DF regime but did not explore its effect on the MF regime. Second, Galí, López-Salido, and Javier (2007) found that the fiscal multiplier is significantly affected by a share of liquidity-constrained (LC) consumers.[4] Cogan, Cwik, Taylor, and Wieland (2010) found that including the LC consumers produces almost the same fiscal multiplier as that in the standard NK model. Although Galí (2020a) found the significant role of nominal price stickiness in evaluating the effectiveness of fiscal policies, the study did not investigate the effect of nominal wage stickiness and household heterogeneity on the performance of an MF regime.

We incorporate nominal wage stickiness and LC consumers into Galí (2020a)'s NK model. Thus, we build the tractable TANK model to be as compatible as possible with the results obtained by Galí (2020a). More precisely, following Ascari et al. (2017), we incorporate the role of nominal wage rigidity and LC consumers into the framework of Galí (2020a). As a result, we construct the tractable TANK model to intuitively explore the effect of the fiscal

[3]For instance, Erceg et al. (2000) showed that the central bank does not overcome a policy trade-off between price inflation, wage inflation, and output gap by implementing strict inflation targeting. Several studies have also revealed the importance of considering the effect of nominal wage stickiness on monetary policy in an open economy NK model (Campolmi, 2014, Ida and Okano, 2023, Ida, 2023, Rhee and Turdaliev, 2013).

[4]Unless otherwise specified, as in Ida (2023) and Ida (2024), we refer to LC consumers as households that do not have free access to financial assets. Several studies proposed different naming schemes for LC households. For instance, Galí et al. (2007) referred to LC households as rule-of-thumb households. We also label households with free access to financial assets as Ricardian households. Several studies refer to this type of household as an optimized household.

multiplier under the MF and DF regimes. The government finances its expenditures through three resources: (i) lump-sum taxes for Ricardian and LC consumers, (ii) issuing risk-free nominal bonds, and (iii) issuing non-interest-bearing money. This simple model extension demonstrates how the degree of nominal wage stickiness significantly affects the fiscal multiplier under the MF and DF regimes.

The main findings of this paper are summarized as follows. First, an increased share of LC consumers amplifies the fiscal multiplier under fully flexible nominal wages under the MF and DF regimes. Second, an increased degree of nominal wage stickiness decreases the MF fiscal multiplier in the presence of a sizable share of LC consumers. In other words, as Cogan et al. (2010) argued, this result indicates that introducing the TANK model does not necessarily create a large government-spending multiplier.[5] Third, in our model, the fiscal multiplier under an MF regime outperforms that under a DF regime. Fourth, given the degree of nominal wage stickiness for MF and DF regimes, an increased share of LC consumers enhances the fiscal multiplier under fiscal stimulus via a lump-sum tax cut, namely a tax-cut multiplier. Finally, the degree of nominal price stickiness and the size of government spending shock remain important factors in our model. Accordingly, this paper implies that for empirically plausible parameter values, the MF fiscal stimulus is a more effective tool for stimulating the real economy than the DF regimes in the presence of nominal wage stickiness and LC consumers.

How do our results relate to previous studies regarding the fiscal multiplier? According to Ramey (2019)'s review of empirical studies on fiscal multipliers, the consensus is that the government-spending multiplier is 0.6–1.0 and the tax-cut multiplier is 2.0–3.0 in absolute value. Nakamura and Steinsson (2014) also reported a DF fiscal multiplier of approximately 1.5 in a currency union model assuming the US economy. We discuss how our results are related to the literature based on a benchmark calibration. Consider the case of an MF regime. Based on our benchmark result, the government-spending multiplier under an MF regime is 1.5–3.0. In the case of a tax cut under an MF regime, while the tax-cut multiplier is 0.8–3.0 under flexible nominal wages, the multiplier ranges from 1.0 to 1.5 under highly sticky nominal wages. These

[5]In contrast to our model, Cogan et al. (2010) considered the role of capital stock in Smets and Wouters (2003)'s model with LC consumers. We conjecture that introducing capital stock affects the fiscal multiplier in our model. Although how the introduction of capital stock affects the fiscal multiplier under an MF regime is important to understand, this task is beyond the scope of the paper. We would like to examine this issue in future research.

values may be slightly higher than those obtained in Galí (2020a). Further, consider the case of a DF regime. Under flexible prices and sticky wages, the government-spending multiplier takes ranges from 0.2 to 1.0. Under sticky prices, the multiplier takes a value above unity under flexible wages. In contrast, the multiplier is less than unity under sticky wages if a sizable share of LC consumers is absent. These results align with those obtained by Broer et al. (2023) and Ramey (2019).

The intuition behind these results is as follows. In the case of flexible nominal wages, as we will show, government spending generates a higher wage growth rate through an increase in the labor demand of Ricardian and LC consumers. This higher wage growth rate boosts the LC households' disposable income; thus, their consumption is increased. Because a government spending shock is generally expected to cause a crowding-out effect, a rise in the real interest rate reduces Ricardian consumption. In the case of flexible nominal wages, an increased share of LC consumers directly stimulates aggregate consumption because a rise in LC consumers' consumption outweighs a decline in Ricardian consumption. This result is consistent with the finding of Galí et al. (2007). Conversely, introducing nominal wage stickiness makes nominal wages less responsive to government spending shocks. This implies that an increase in LC consumers' consumption is dampened by nominal wage rigidity. However, increasing government spending causes the real interest rate to fall substantially under an MF regime, thus significantly boosting Ricardian household consumption. Even when the share of LC consumers is considerably small, the fiscal authority can obtain a fiscal multiplier that exceeds unity under an MF regime. A similar discussion applies to the case of a DF regime, except for a drop in the real interest rate under an MF regime.

The remainder of this paper is constructed as follows. Section 2 reviews previous studies to highlight this paper's contribution, and Section 3 develops the TANK model with nominal wage stickiness. Section 4 explores the effect of nominal wage stickiness on fiscal multiplier in a TANK model for MF and DF regimes. Section 5 explores several sensitivity experiments. Section 6 examines the impact of a change in nominal wage rigidity on the fiscal stimulus through tax cuts. Section 7 provides further extensions, and Section 8 concludes the paper.

2 Related literature

This section reviews the literature on a fiscal multiplier in a sticky price model.[6] The standard RBC model indicates that a government spending shock reduces aggregate consumption, which is inconsistent with the time series analyses (Blanchard and Perotti, 2002). Moreover, similar to the standard RBC model, Galí et al. (2007) argued that the standard NK model still suffers from this counterintuitive result, which Bilbiie (2009) labeled the fiscal policy puzzle. One solution to this puzzle is the TANK model, which assumes the inclusion of LC consumers in the NK model. In fact, Galí et al. (2007) found that government spending yields a positive response in aggregate consumption by increasing the LC consumers' consumption in the TANK model. In addition, they showed that the fiscal multiplier is greater in the TANK model than in the representative-agent NK (RANK) model. However, the authors did not consider the effect of nominal wage stickiness on the fiscal multiplier.

This study is related to the work of Colciago (2011), who revealed the role of nominal wage stickiness in accounting for the effect of government spending on the real economy.[7] Our study is different from that of Colciago (2011) in the following ways. First, he did not address the impact of changes in nominal wage stickiness on the fiscal multiplier. Second, unlike his study, the present study addresses the impact of nominal wage stickiness on the fiscal multiplier under MF and DF regimes. Third, while he did not focus on the role of a tax cut, we show the interaction effect between nominal wage stickiness and the degree of LC consumers on the multiplier under a tax cut.

Broer et al. (2023)'s research is also related to our study. They considered the effect of household heterogeneity on the fiscal multiplier in a HANK model and showed that the fiscal

[6] A number of previous studies have examined the effectiveness of fiscal policies. Ramey (2019) reviewed the empirical studies of fiscal policies. Eggertsson (2011), Woodford (2011), and Kaszab (2016) examined whether government spending or tax policy is effective for stimulating the real economy under the ZLB in the NK model. Owyang, Ramey, and Zubairy (2013) and Ramey and Zubairy (2018) reported the empirical assessment of the fiscal policy under the ZLB. Meanwhile, Liu, Huang, and Lai (2022) examined the paradox of toil at the ZLB in a TANK model. Moreover, Auclert, Rognlie, and Straub (2018), Auclert, Bardóczy, and Rognlie (2021), and Kopiec (2022) considered the effectiveness of fiscal policies in a HANK model.

[7] Bilbiie (2008) found that an increased share of LC consumers will likely render the rational expectations equilibrium indeterminate. Colciago (2011) argued that the presence of sticky nominal wages alleviates the TANK model's indeterminacy problem.

multiplier takes a value of around unity under sticky wages. They also showed that this result is unaffected by introducing sticky nominal prices. Unlike their study, we concentrate on the effect of nominal price and wage stickiness on the MF fiscal stimulus in a TANK model.[8]

Our study is most related to that of Galí (2020a), who investigated the effect of an MF fiscal stimulus in the standard NK model. He argued that nominal price stickiness should be considered when evaluating the effect of fiscal stimulus through government spending or tax cuts. Moreover, he demonstrated that the fiscal multiplier is generally larger in the case of an MF regime than a DF regime.[9] However, he did not consider the role of nominal wage stickiness. Furthermore, while we document the importance of household heterogeneity in an NK model, he examined the effect of an MF fiscal stimulus in a standard sticky price model.

Finally, this study is related to the work of Punzo and Rossi (2022), who examined the effect of an MF fiscal stimulus in the TANK model.[10] They focused on the effect of an MF fiscal stimulus on the fiscal policy's redistribution channel and considered the welfare implications of the MF fiscal stimulus based on the central bank's loss function derived from the second-order approximation of the household's utility function. However, their model did not account for the role of nominal wage stickiness or the magnitude of the fiscal multiplier.

To the best of our knowledge, no study has attempted to thoroughly explore the effect of nominal wage stickiness on fiscal stimulus in an NK model with household heterogeneity. Our research contributes to the literature as follows. First, we constructed a tractable TANK model with nominal wage stickiness and thoroughly investigated the effect of nominal wage stickiness on fiscal multiplier under both MF and DF regimes. Second, we showed that the multiplier possibly decreases with an increase in nominal wage stickiness even in the model with household heterogeneity. In particular, given a sizable share of LC consumers, increasing

[8] Debortoli and Galí (2017) argued that there is no difference between the TANK and HANK models in terms of aggregate shocks. Further, while Cogan et al. (2010) reported a smaller value of the fiscal multiplier in a TANK model, which seems inconsistent with the results derived by Galí et al. (2007), they did not focus on the multiplier under an MF regime. In contrast, we obtained a sizable value of the fiscal multiplier under an MF regime in a TANK model with nominal wage stickiness.

[9] Tsuruga and Wake (2019) explored the effect of an MF fiscal stimulus in an NK model in which transmission lags regarding government spending were introduced. Moreover, Okano and Eguchi (2023) extended the framework of Galí (2020a) to the case of a small open economy.

[10] Kaszab (2016) considered the role of a labor tax cut in a TANK model with the ZLB.

the degree of nominal wage stickiness lowers the government-spending multiplier under the MF regime. Previous studies have not addressed this novel finding.

3 Model

This section provides the model description. Our model extends the framework of Galí (2020a) to the TANK model with nominal wage stickiness. More concretely, following Ascari et al. (2017), we incorporate the role of nominal wage stickiness into the standard TANK model. Next, following Galí (2020a), we examine the role of MF fiscal stimulus. Section 3.1 describes the nonpolicy blocks, which include households and firms. Section 3.2 describes the fiscal and monetary authorities' policy blocks. Based on the study by Galí (2020a), the structural model is constructed by the assumption of perfect foresight. Finally, unless otherwise specified, hatted variables in this paper represent the logarithmic deviation from the steady state. More precisely, the log-linearized variables around the steady state are represented by $\hat{H}_t = \log(H_t/H)$, where H denotes the steady-state value.

3.1 Nonpolicy blocks

3.1.1 Households

Following Bilbiie (2008) and Galí et al. (2007), we consider the standard TANK model. More concretely, a fraction $1-\lambda$ of households can access financial markets, whereas the remaining share λ cannot. On the one hand, a fraction of $1-\lambda$ comprises Ricardian households that can freely access financial markets. They have access to the complete set of state-contingent securities available in the financial market. On the other hand, a fraction of λ represents LC consumers who cannot trade financial assets in the financial market. Regarding wage determination, following Ascari et al. (2017), this paper assumes that a labor union determines the nominal wage and that each union faces Calvo-type nominal wage rigidity.[11] Thus, the presence of a staggered nominal wage leads to the wage NK Phillips curve.

[11] We present the result under an alternative labor market specification in Section 7.

Preference

Households obtain utility from consumption, real money balances, and disutility from supplying labor.[12]

$$\begin{aligned} U_{k,t} &= \sum_{t=0}^{\infty} \beta^t \Big[u(C_{k,t}) + h(L_{k,t}) - v(N_{k,t}(j)) \Big] Z_t, \\ &= \sum_{t=0}^{\infty} \beta^t \left[\frac{C_{k,t}^{1-\sigma}}{1-\sigma} + \frac{L_{k,t}^{1-\mu}}{1-\mu} - \frac{N_{k,t}(j)^{1+\varphi}}{1+\varphi} \right] Z_t, \end{aligned} \tag{1}$$

where for $k = o, r$. $C_{k,t}$, $L_{k,t}$, $N_{k,t}(j)$, and Z_t denote consumption, real money balances, the labor supply for type j, and an exogenous preference shock, respectively. The subscripts o and r represent Ricardian and LC consumers, respectively.

Labor market

Following Ascari et al. (2017), we consider that the nominal wage earned by each household is set by the labor type-specific union, indexed by j ($j \in [0, 1]$). The nominal wage is fixed by union j. The labor supply $N_t(j)$ is given as follows:

$$N_t(j) = \left(\frac{W_t(j)}{W_t} \right)^{-\epsilon_w} N_t^d, \tag{2}$$

where $N_t(j)$ denotes the labor supply in union j, $W_t(j)$ is the nominal wage set by union j, and N_t^d denotes the demand for labor. The parameter ϵ_w is the elasticity of substitution for individual labor. Following Ascari et al. (2017), we ignore the discrepancy in the wage difference between households because of the assumption that $N_t(j)$ is identical for both Ricardian and LC consumers:

$$N_t = \int_0^1 N_t(j) dj. \tag{3}$$

Thus, we obtain the following common labor income:

$$\int_0^1 W_t(j) N_t(j) dj = N_t^d \int_0^1 W_t(j) \left(\frac{W_t(j)}{W_t} \right)^{-\epsilon_w} dj. \tag{4}$$

[12]Similar to Galí (2020a), we assume the money in the utility function. See Tsuruga and Wake (2019) for a detailed discussion of the model in which households face a cash-in-advance constraint.

Ricardian households

A fraction of $1-\lambda$ corresponds to a share of Ricardian households. The Ricardian household maximizes the aforementioned utility function, subject to the following budget constraint:

$$P_t C_{o,t} + Q_{t,t+1} B_{o,t+1} + M_{o,t} = B_{o,t} + M_{o,t-1} + N_t^d \int_0^1 W_t(j) \left(\frac{W_t(j)}{W_t} \right)^{-\epsilon_w} dj + \Gamma_{o,t} - T_{o,t},$$

where $B_{o,t}$ represents nominal bonds held for one period and $\Gamma_{o,t}$ denotes the dividends earned from intermediate goods firms. $M_{o,t}$ and $T_{o,t}$ denote nominal money stock and lump-sum tax held in Ricardian households, respectively. We assume that Ricardian households have access to state-contingent bonds traded in a complete financial market, and we introduce the following stochastic discount factor $Q_{t,t+1}$:

$$Q_{t,t+1} = \frac{1}{1+i_t}, \tag{5}$$

where i_t is the short-term nominal interest rate.

From the utility maximization problem, we obtain the following optimal conditions:

$$\frac{1}{1+i_t} = \beta \left[\frac{u_c(C_{o,t+1})}{u_c(C_{o,t})} \frac{P_t}{P_{t+1}} \right], \tag{6}$$

$$\frac{h_l(L_{o,t})}{u_c(C_{o,t})} = \frac{i_t}{1+i_t}. \tag{7}$$

Equation (6) represents the consumption Euler equation, and Equation (7) implies the money demand function.

LC households

A fraction of λ cannot access financial markets. As previously stated, they have the same periodic utility function as Ricardian households, but their budget constraints are given as follows:

$$P_t C_{r,t} + M_{r,t} = M_{r,t-1} + N_t^d \int_0^1 W_t(j) \left(\frac{W_t(j)}{W_t} \right)^{-\epsilon_w} dj - T_{r,t}, \tag{8}$$

where $M_{r,t}$ and $T_{r,t}$ denote nominal money stock and lump-sum tax held in LC households, respectively. Unlike Ricardian households, because LC households cannot implement intertemporal consumption smoothing by trading state-contingent bonds in bond markets, they choose consumption and money stock to maximize their utility. Log-linearizing the LC consumers'

budget constraints leads to

$$\hat{C}_{r,t} + \chi(\hat{l}_{r,t} - \hat{l}_{r,t-1} - \pi_t) = \frac{(1-\alpha)}{\mu^p}(\hat{w}_t + \hat{N}_t) - \hat{t}_{r,t}, \tag{9}$$

where $l_{r,t}$ and π_t denote LC households' real money balances and price inflation. The subsequent section presents the parameters regarding α, μ_p, and χ.

3.1.2 Wage setting in a labor union

Both Ricardian and LC households delegate the determination of nominal wage to a labor union. Following Ascari et al. (2017), the nominal wage setting is subject to Calvo-type staggered wage contracts. Thus, a fraction of $1-\theta_w$ can change nominal wages in its union but a fraction of θ_w cannot. Accordingly, the labor union solves the following maximization problem:

$$\max_{\tilde{W}_t} \sum_{s=0}^{\infty} (\theta_w \beta)^s \Big[(1-\lambda) U_{o,t+s} + \lambda U_{r,t+s} \Big].$$

The first-order condition of this problem is given as follows:

$$\sum_{s=0}^{\infty} (\theta_w \beta)^s V_n(N_{t+s}) N_{t+s}^d W_{t+s}^{\epsilon_w} \left[\left(\frac{\lambda}{MRS_{o,t+s}} + \frac{1-\lambda}{MRS_{r,t+s}} \right) \frac{\tilde{W}_t}{P_{t+s}} - \mu_w \right] = 0, \tag{10}$$

where $\mu_w = \epsilon_w/(\epsilon_w - 1)$ and $\tilde{W}_t$ denotes the optimal nominal wage. The aggregate wage index is defined as follows:

$$W_t = \left[\int_0^1 W_t(j)^{1-\epsilon_w} dj \right]^{\frac{1}{1-\epsilon_w}}. \tag{11}$$

Under a Calvo-type wage setting, this equation can be rewritten as follows:

$$W_t = \left[(1-\theta_w) \tilde{W}_t^{1-\epsilon_w} + \theta_w W_{t-1}^{1-\epsilon_w} \right]^{\frac{1}{1-\epsilon_w}}. \tag{12}$$

Log-linearizing optimal nominal wage leads to the following wage NK Phillips curve:

$$\pi_t^w = \beta \pi_{t+1}^w - \delta_w \hat{\mu}_t^w, \tag{13}$$

where π_t^w (=$\log(W_t/W_{t-1})$) denotes wage inflation. Further, the average wage markup is given by

$$\hat{\mu}_t^w = \hat{w}_t - \left(\sigma + \frac{\varphi}{1-\alpha} \right) \hat{Y}_t, \tag{14}$$

where $\hat{w}_t$ denotes log-linearized real wage and α is the degree of decreasing return to scale in the intermediate goods firms' production function. The coefficient δ_w is defined by

$$\delta_w = \frac{(1-\theta_w)(1-\theta_w\beta)}{\theta_w(1+\varphi\epsilon_w)}.$$

3.1.3 Firms

There are two production sectors: the final and intermediate goods sectors. The final goods sector produces final goods using intermediate goods and is characterized by perfect competition. Conversely, the intermediate goods sector is characterized by monopolistic competition and Calvo (1983)'s price setting.

Final goods firms

The final goods sector produces final goods according to the following constant elasticity of substitution (CES) aggregate:

$$Y_t = \left[\int_0^1 Y_t(z)^{\frac{\epsilon_p - 1}{\epsilon_p}} dz\right]^{\frac{\epsilon_p}{\epsilon_p - 1}}, \tag{15}$$

where Y_t is aggregate output, $Y_t(z)$ is the demand for intermediate goods produced by firm z, and ϵ_p is the elasticity of substitution. Under the CES aggregate, the demand function is given as follows:

$$Y_t(z) = \left(\frac{P_t(z)}{P_t}\right)^{-\epsilon_p} Y_t, \tag{16}$$

and the price level is defined as follows:

$$P_t = \left[\int_0^1 P_t(z)^{1-\epsilon_p} dz\right]^{\frac{1}{1-\epsilon_p}}, \tag{17}$$

where $P_t(z)$ is the price for intermediate goods produced by firm z.

Intermediate goods firms

Firm z's production function is given by

$$Y_t(z) = A_t N_t(z)^{1-\alpha}, \tag{18}$$

with

$$N_t(z) = \left[\int_0^1 (N_t(j,z))^{\frac{\epsilon_w - 1}{\epsilon_w}} dj\right]^{\frac{\epsilon_w}{\epsilon_w - 1}}. \tag{19}$$

Additionally, A_t denotes an aggregate productivity disturbance.

Following Calvo (1983), we assume that nominal price rigidity exists in the intermediate goods sector. A fraction $1 - \theta_p$ of all firms adjusts their price, whereas the remaining fraction

of firms θ_p does not. We now consider intermediate firms that can adjust their prices. When revising their prices, these firms account for the uncertainty of when they can adjust prices next. In this case, the intermediate firm's optimization problem is given as follows:

$$\sum_{s=0}^{\infty} \theta_p^s Q_{t,t+s} Y_{t+s}(z)(P_t^* - P_{t+s} MC_{t+s,t}), \tag{20}$$

where P_t^* is the firm's optimal price and $MC_{t+s,t}$ denotes the real marginal cost in period $t+s$ for a firm that last reset its price in period t. The first-order condition of this maximization problem is as follows:

$$\sum_{s=0}^{\infty} \theta_p^s Q_{t,t+s} Y_{t+s}(z)(P_t^* - \mu_p P_{t+s} MC_{t+s,t}) = 0, \tag{21}$$

where the variable $\mu_p = \epsilon_p/(\epsilon_p - 1)$ is the price markup. Log-linearizing optimal nominal prices yields the following price NK Phillips curve:

$$\pi_t = \beta \pi_{t+1} - \zeta_p \hat{\mu}_t^p, \tag{22}$$

where the variable $\hat{\mu}_t^p$ denotes the average price markup, which is given by

$$\hat{\mu}_t^p = -\frac{\alpha}{1-\alpha} \hat{Y}_t - \hat{w}_t, \tag{23}$$

and

$$\zeta_p = \frac{(1-\theta_p)(1-\theta_p \beta)}{\theta_p} \frac{1-\alpha}{1-\alpha+\alpha\epsilon_p}.$$

3.2 Policy blocks

Except for a tax rule for Ricardian and LC consumers, the policy blocks are similar to those considered by Galí (2020a). Below, we provide brief descriptions of policy blocks and equilibrium conditions.

Fiscal and monetary authorities

Except for the specification of tax rules, following Galí (2020a), we assume that under the coordinated fiscal and monetary authorities, the government finances its expenditures through three resources: (i) lump-sum taxes for Ricardian and LC consumers, (ii) issuing risk-free

nominal bonds, and (iii) issuing non-interest-bearing money. The consolidated government budget constraints are given as follows:

$$P_t G_t + B_{t-1}(1 + i_{t-1}) = P_t T_t + B_t + \Delta M_t. \tag{24}$$

Dividing both sides by P_t, the government budget constraints can be rewritten in real terms as shown below:

$$G_t + \mathcal{B}_{t-1}\mathcal{R}_{t-1} = T_t + \mathcal{B}_t + \frac{\Delta M_t}{P_t}, \tag{25}$$

where $\mathcal{B}_t = B_t/P_t$ and $\mathcal{R}_t = (1 + i_t)P_t/P_{t+1}$. Following Galí (2020a), we assume that zero-seigniorage holds at the steady state with $\Delta M = 0$. The consolidated budget constraints at the steady state are given as follows:

$$T = G + \rho\mathcal{B},$$

where $\mathcal{R} = 1 + \rho$ and ρ denotes a time preference rate.

Following Galí (2020a), we provide the level of seigniorage expressed in terms of steady-state output as follows:

$$\frac{\Delta M_t/P_t}{Y} = \left(\frac{\Delta M_t}{M_{t-1}}\right)\left(\frac{P_{t-1}}{P_t}\right)\frac{L_{t-1}}{Y} \simeq \chi \Delta m_t, \tag{26}$$

where $L_t = M_t/P_t$, $m_t = \log M_t$, and $\chi = L/Y$.

Let $\hat{b}_t = (\mathcal{B}_t - \mathcal{B})/Y$, $\hat{g}_t = (G_t - G)/Y$, and $\hat{t}_t = (T_t - T)/Y$. Log-linearizing the consolidated budget constraints leads to

$$\hat{b}_t = (1 + \rho)\hat{b}_{t-1} + b(1 + \rho)(\hat{i}_{t-1} - \pi_t) + \hat{g}_t - \hat{t}_t - \chi \Delta m_t, \tag{27}$$

where $b(= \mathcal{B}/Y)$ represents the target debt ratio. Further, the other variables are defined as $\hat{t}_t = (1 - \lambda)\hat{t}_{o,t} + \lambda \hat{t}_{r,t}$, $\hat{t}_{k,t} = (T_{k,t} - T)/Y$ (for $k = o, r$), and $\hat{i}_t = \log[(1 + i_t)/(1 + \rho)]$. Variable π_t $(= \log(P_t/P_{t-1}))$ denotes price inflation.

Unlike the RANK model, as our model is based on the TANK model, we can consider that the government levies taxes on both Ricardian and LC consumers. Specifically, we assume that the taxes for both consumers are as follows:

$$\hat{t}_{k,t} = \psi_{k,b}\hat{b}_{t-1} + \hat{t}^*_t, \tag{28}$$

for $k = o, r$ and $\hat{t}^*_t$ denotes the exogenous tax shock.

Substituting Equations (28) into Equation (27) leads to

$$\hat{b}_t = \Big[1 + \rho - (1-\lambda)\psi_{o,b} - \lambda\psi_{r,b}\Big]\hat{b}_{t-1} + b(1+\rho)(\hat{i}_{t-1} - \pi_t) + \hat{g}_t - \hat{t}_t^* - \chi\Delta m_t. \tag{29}$$

We assume the condition $(1-\lambda)\psi_{o,b}+\lambda\psi_{r,b} > \rho$, so that the debt ratio converges to its long-run target value $\mathcal{B}$.

Experiments

Following Galí (2020a), we consider two fiscal interventions in the preceding model. The first intervention is characterized by government spending, which is assumed by

$$\hat{g}_t = \delta^t > 0, \tag{30}$$

where $t = 0, 1, 2, \cdots$. The parameter $\delta \in [0, 1)$ indicates the persistence of the exogenous fiscal stimulus. The second intervention is characterized by a tax cut, which is assumed by

$$\hat{t}_t^* = -\delta^t < 0, \tag{31}$$

where $t = 0, 1, 2, \cdots$.

Additionally, following Galí (2020a), we implemented these two interventions under two alternative policy regimes for the government to meet its financing needs. We classify an MF fiscal stimulus as a first regime, assuming that seigniorage is adjusted every period to keep real debt constant. Thus, to satisfy $\hat{b}_t = 0$ for all t, we adjusted the money stock using the following rule:

$$\Delta m_t = \frac{1}{\chi}\Big[\delta^t + b(1+\rho)(\hat{i}_{t-1} - \pi_t)\Big]. \tag{32}$$

Thus, the government is not required to increase taxes and debts in response to a change in government spending or a tax cut. In contrast, the central bank adjusts the money stock to satisfy the government's financing needs at the expense of controlling the nominal interest rate.

Next, we consider the DF fiscal stimulus as a second regime. As Galí (2020a) assumed, the fiscal authority in this regime issues government debt to finance its fiscal spending. Therefore, it eventually adjusts the tax path for both Ricardian and LC consumers to meet the long-run debt target. In this regime, the central bank controls the nominal interest rate using the standard Taylor rule (Taylor, 1993), which is given by

$$\hat{i}_t = \rho + \phi_\pi \pi_t, \tag{33}$$

where ϕ_π denotes the inflation stabilization coefficient in the Taylor rule.[13] Therefore, under a DF regime, the money stock is endogenously adjusted via a money demand function:

$$\hat{l}_{k,t} = \eta_c \hat{C}_{k,t} - \eta_r \hat{i}_t, \tag{34}$$

for $k = o, r$. The parameters η_c and η_r denote the income and interest elasticity of money demand, respectively.[14] Note that in contrast to Galí (2020a), the money demand function in our study is characterized by Ricardian and LC consumers.

3.3 Equilibrium conditions

Finally, we briefly explain the equilibrium conditions, except for policy and nonpolicy blocks. The remaining equilibrium conditions are given as follows:

$$Y_t = C_t + G_t, \tag{35}$$

$$C_t = (1-\lambda)C_{o,t} + \lambda C_{r,t}, \tag{36}$$

$$B_t = (1-\lambda)B_{o,t}, \tag{37}$$

$$\Gamma_t = (1-\lambda)\Gamma_{o,t}, \tag{38}$$

$$M_t = (1-\lambda)M_{o,t} + \lambda M_{r,t}, \tag{39}$$

$$T_t = (1-\lambda)T_{o,t} + \lambda T_{r,t}. \tag{40}$$

Equation (35) represents the goods market clearing condition, and Equation (36) denotes aggregate consumption. The conditions (37) and (38) denote bond market clearing and aggregate dividend, respectively. Equations (39) and (40) denote the equilibrium condition for the money market and the aggregate tax level, respectively.

4 Main results

This section provides this study's main results. Section 4.1 details the calibrated values used in this paper. Section 4.2 examines the effect of government spending under an MF regime, and Section 4.3 reports the government-spending multiplier under a DF regime. Based on our main results, Section 4.4 argues about the impact of the degree of nominal wage stickiness on the fiscal multiplier.

[13] In contrast to our study, Galí (2020a) considered strict inflation targeting instead of using a Taylor rule.

[14] This equation holds unless the nominal interest rate reaches its ZLB.

4.1 Calibration

We explain the values of the deep parameters calibrated in this paper. We adopt the calibrated values from previous studies. Except for the proportion of LC households and the degree of nominal wage rigidity, most calibrated values are based on those used by Galí (2020a). The parameters σ and φ are set to 1.0 and 5.0, respectively. Concerning the degree of nominal price stickiness, we set θ_p to 0.75 as a benchmark-calibrated value based on the standard NK literature (Eichenbaum and Fisher, 2007).[15] For the value of the money demand function for Ricardian and LC consumers, η_c and η_r are set to 1.0 and 4.0, respectively. The elasticity of substitution (ϵ_p) is set to 9.0, and the elasticity of substitution for labor services (ϵ_w) is set to 9.0. We set the degree of decreasing return to scale in the production function (α) to 0.25.

Subsequently, we will explain how to choose the value of the degree of nominal wage rigidity. We set θ_w to 0.75 as a benchmark value, which is consistent with previous research on the standard NK model with nominal wage rigidity (Christiano, Eichenbaum, and Evans, 2005, Erceg et al., 2000, Smets and Wouters, 2003, 2007). Because we explore how wage flexibility affects the impact of an MF regime on macroeconomic dynamics in both normal and liquidity trap times, we also consider the parameter range of θ_w from 0 to 1.[16]

We now discuss calibrating the proportion of LC households corresponding to LC consumers' share. Kaplan, Violante, and Weidner (2014) argued that for the United States, Canada, Australia, the United Kingdom (UK), Germany, France, Italy, and Spain, the share of LC households ranges from 20% to 35%.[17] Almgren, Gallegos, Kramer, and Lima (2022) illustrated that the fraction of LC consumers ranges from 10% in Malta to nearly 65% in Latvia. In this paper, we set λ to 0.25 as the benchmark value and assess the robustness of the results by employing several alternative values for 0, 0.1, 0.25, and 0.4. The values of $\lambda = 0.1$ and $\lambda = 0.25$ are in line with the empirical values reported by Almgren et al. (2022) and Kaplan et al. (2014). The case for $\lambda = 0.4$ is discussed in Bilbiie (2008).

Finally, we explain the method for calibrating the policy block parameters. In the Taylor rule, the inflation stabilization coefficient is fixed to 1.5 (Taylor, 1993, Woodford, 2003). To

[15] See Nakamura and Steinsson (2008) for a detailed discussion about the frequency of nominal price adjustments.

[16] The introduction of price and wage inflation persistence is discussed in Section 7.

[17] See Kaplan et al. (2014) for a detailed discussion about the empirical issue on the share in LC consumers.

examine the impact of wage flexibility on an MF regime as simply as possible, we assume that the tax adjustment parameter satisfies $\psi_b^o = \psi_b^r$. Next, following Galí (2020a), we set the tax adjustment parameter ψ_b^k (for $k = o, r$) to 0.02, target debt ratio b to 2.4, and persistence parameter δ to 0.5.

4.2 MF regime

We first examine the impulse responses of several key macro variables to increases in government spending to capture model dynamics of our model. Figure 1 shows the impulse responses to government spending shocks when LC consumers and nominal wage rigidities are considered. Figure 1 indicates that when nominal wage stickiness and LC consumers coexist, the economy experiences a substantial increase in output. Furthermore, regardless of the presence of LC consumers, the response of price inflation to the shock is smaller under sticky nominal wages than under fully flexible nominal wages. Labor supply seems to increase despite the degree of nominal wage stickiness and a share of LC consumers. In contrast, disposable income becomes larger under flexible nominal wages than under sticky wages.

[Figure 1 around here]

Moreover, if nominal wages are sticky, the nominal interest rate decreases in response to a government spending shock. Therefore, compared with flexible nominal wages, the real interest rate falls even further under an MF regime. Consequently, aggregate consumption increases in our model; hence, the fiscal policy puzzle pointed out by Blanchard and Perotti (2002), who argued that government spending decreases consumption, does not emerge. In contrast to Galí (2020a), we found that an increase in aggregate consumption is larger under sticky nominal wages. In summary, except for the presence of LC consumers, in our model, the effect of an MF fiscal stimulus on output is greater in the NK model with sticky nominal wages than in those with flexible nominal wages. This result is not observed in the framework of Galí (2020a).

We then examine the effect of the degree of nominal wage stickiness on the government-spending multiplier under an MF regime. Following Galí (2020a), we calculate the cumulative output multiplier, $(1-\delta)\sum_{t=0}^{\infty}\hat{y}_t$, as the measure of the effectiveness of fiscal policy.[18] Figure 2 illustrates how the degree of nominal wage stickiness influences the government-spending

[18] We employ this metric in the case of the MF and DF regimes.

multiplier under an MF fiscal stimulus. Consider the case of fully flexible nominal wages, namely, $\theta_w = 0$. A higher proportion of LC consumers amplifies the impact of government spending on output. Note that under an MF fiscal stimulus, the multiplier exceeds unity even in the case of $\lambda = 0$. This result is consistent with Galí (2020a).

[Figure 2 around here]

Then, we explore how the degree of nominal wage stickiness affects the government-spending multiplier under an MF regime. First, when the proportion of LC consumers is considerably large (i.e., $\lambda = 0.4$), the multiplier drastically decreases as nominal wages become stickier. The multiplier appears to remain unaffected by an increase in θ_w when this parameter exceeds 0.4. Second, the multiplier also decreases with an increased value of θ_w when $\lambda = 0.25$. Third, in contrast to the previous two cases, for a smaller proportion of LC consumers, the cumulative effect of government spending on output increases significantly as θ_w increases. Summing up, the magnitude of how wage stickiness affects the fiscal multiplier is determined entirely by the share of LC households.

The intuition of this result is as follows. When nominal wages are sticky, a rise in price inflation can reduce the real wages because nominal wages are unaffected by government spending. Accordingly, a decrease in real wages offsets an increase in LC consumers' consumption. We call this the *negative income effects* of price inflation on Ricardian and LC consumers' consumption. Conversely, Ricardian consumption increases steadily after government spending because lowering the nominal interest rate decreases the real interest rate. The Ricardian households increase their consumption via an intertemporal substitution effect in their consumption Euler equation. Hence, if the share of LC consumers is small, an increase in Ricardian consumption may outweigh a weaker demand for LC consumer consumption. Conversely, in the case of a large share of LC consumers, the multiplier is smaller under sticky nominal wages than flexible nominal wages. This disparity occurs because the LC consumers' negative income effect may dominate the Ricardian consumers' intertemporal substitution effect. In other words, it is possible that an increased share of LC consumers dampens the impact of government spending on output if sticky nominal wages are introduced. We call this mechanism *the sticky wage channel of fiscal stimulus*. Despite a share of LC consumers, the multiplier exceeds unity under sticky nominal wages in contrast to the case of flexible nominal wages. The above logic also applies to both MF and DF regimes.

We summarized the preceding results as follows. In a TANK model, the presence of nominal wage stickiness substantially affects the impact of government spending on output. We demonstrated that increased government spending under the MF regime causes intertemporal substitution effects in Ricardian household consumption via a change in the real interest rate. However, we also found that the negative income effects on LC household consumption occur via the sticky wage channel of fiscal stimulus. Our model shows that the magnitude of the fiscal multiplier is determined by the relative impacts of these two effects.

4.3 DF regime

We examine the effect of a government spending shock on macrovariables under a DF regime to consider the role of an MF regime. Figure 3 illustrates the DF regime's impulse response to a government spending shock. First, consider the case for flexible nominal wages; an increase in government spending stimulates output while decreasing consumption in an economy without LC consumers. This implies that the fiscal policy puzzle does not disappear even when the presence of LC consumers is assumed.[19] The shock raises the nominal interest rate, which increases the real interest rate despite rising price inflation. Under a DF regime, the real debt rises due to increased government spending. In contrast to the case of no LC consumers, an increase in LC consumer share stimulates output and aggregate consumption. This response is consistent with the finding of Galí et al. (2007).

[Figure 3 around here]

Further, we explore the case for sticky nominal wages. First, an increase in output occurs regardless of the presence of LC consumers. Moreover, while wage inflation no longer responds to a government spending shock, price inflation rises slightly. The response of a nominal interest rate is much smaller under sticky nominal wages than under flexible nominal wages because the response of price inflation is dampened. This results in a smaller drop in aggregate consumption in the case of $\lambda = 0.25$. The result that sticky nominal wages dampen a decline in aggregate consumption in a TANK model is consistent with the finding of Colciago (2011). An increase in output and aggregate consumption is larger when $\lambda = 0.25$ than when $\lambda = 0$. The response

[19]The discussion about eliminating this puzzle in our model is beyond the scope of this paper. See Bilbiie (2009) for a detailed theoretical discussion on the fiscal price puzzle.

of macrovariables under sticky wages (vs. flexible nominal wages) appears to be unaffected by the degree of LC consumers. Moreover, as in the case of an MF regime, an increase in labor supply does not depend on both the degree of nominal wage stickiness and the share of LC consumers. Disposable income also becomes larger under flexible nominal wages than under sticky ones.

Figure 4 shows the multiplier of government spending under a DF regime. First, consider the case for flexible nominal wages. A higher share of LC consumers generates a larger fiscal multiplier, as in the case of an MF regime. For instance, in the case of $\lambda = 0.4$, the multiplier takes a value of approximately 2.4 under a DF regime. When the LC consumers are removed from the model, the multiplier falls to approximately 0.6. Next, consider the case for sticky nominal wages. Figure 4 depicts that the multiplier in the absence of LC consumers does not dominate the multiplier in the presence of LC consumers while moderate nominal wage stickiness exists. Figure 4 shows that an increased value of θ_w lowers the multiplier under a DF regime in a higher share in LC consumers, similar to the MF regime.

[Figure 4 around here]

The intuition of this result is as follows. When nominal wages are sticky, a moderate rise in price inflation causes an attenuated decrease in real wages because government spending has little impact on nominal wages. Therefore, a reduction in real wages leads to a decrease in LC consumers' consumption. In contrast, the Ricardian household consumption remains nearly unchanged by government spending because a smaller increase in the nominal interest rate counteracts a rise in the real interest rate. This matches the findings of Colciago (2011). Thus, as long as the share of LC consumers is small, the effect of preventing a drop in Ricardian consumption outweighs the effect of preventing a weaker demand for LC consumer consumption from a drop in real wages. Consequently, the output response to government spending becomes larger under sticky nominal wages than under flexible ones. However, similar to an MF regime, an increased share of LC consumers mitigates the impact of government spending on output as nominal wages become stickier.

Finally, we compare the impact of government spending under an MF versus a DF regime. Figure 5 shows the government-spending multiplier under the two regimes. Fiscal multiplier is always smaller under a DF regime than under an MF regime, even when both LC consumers and nominal wage rigidity are considered in the model. This result is consistent with that

obtained by Galí (2020a), who found that the effect of an MF regime generally dominates that of a DF regime. Moreover, the presence of LC consumers enhances the fiscal multiplier under MF and DF regimes. Furthermore, we found that the DF fiscal stimulus is less responsive to an increase in nominal wages. Finally, the ability to stimulate the economy is greater under the MF regime than under the DF regime in the presence of LC consumers; monetary transfers from the fiscal authorities under an MF fiscal stimulus can directly stimulate Ricardian and LC consumers' consumption rather than a DF fiscal stimulus.

[Figure 5 around here]

Summing up, our result underscores the importance of both LC consumers and nominal wage stickiness. This implies that under a DF regime, for the value of $\lambda = 0.25$, the government-spending multiplier is less sensitive to the degree of nominal wage stickiness. In contrast, in the MF regime, if the value of θ_w is considerably small, a substantial discrepancy exists between the case of $\lambda = 0.25$ and that of no LC consumer. Notably, the difference between the two cases becomes smaller as the value of θ_w increases. Therefore, this paper emphasizes the significant role of nominal wage rigidity in accounting for the macroeconomic impact of fiscal stimulus in a TANK model. In other words, to the best of our knowledge, no study has accounted for the interactive effect of both LC consumers and nominal wage stickiness on the fiscal multiplier.

4.4 Discussion

Our TANK model demonstrates that the fiscal multiplier of an MF regime is much larger than that of a DF regime. As shown by Galí (2020a), the impact of real interest rates on fiscal stimulus captures the key difference between MF and DF regimes. In the RANK model with sticky prices and flexible wages, the authority manipulates nominal interest rates to stabilize price inflation under the DF regime. If the fiscal stimulus triggers price inflation, the central bank controls the nominal interest rates. Such a monetary contraction raises real interest rates, thereby reducing Ricardian consumers' current consumption. In contrast, the money supply should be increased to offset the increase in real government debt under the MF regime. As a result, an increased money supply leads to price inflation and a decrease in real interest rates, thus stimulating Ricardian consumers' current consumption. Moreover, one can expect the direct effect of money injection by fiscal authority on output under an MF regime.

More importantly, we emphasize the importance of considering that nominal wage stickiness significantly impacts the fiscal multipliers of the MF and DF regimes. Our main message is that for empirically plausible calibrated values, the following conditions may be necessary to fully benefit from the MF regime's fiscal stimulus: (1) nominal wages that are fully flexible and the share of LC consumers is large or (2) nominal wages that are sticky and the share of LC consumers is not large. Our model's degree of nominal wage rigidity is set to 0.75 as a benchmark parameter value. This value is based on the standard NK model with nominal wage stickiness (Christiano et al., 2005, Erceg et al., 2000, Galí, 2011). Additionally, as noted earlier, Kaplan et al. (2014) specified that the proportion of households facing liquidity constraints in the US, Canada, Australia, the UK, Germany, France, Italy, and Spain is between 20% and 35%. Almgren et al. (2022) reported that the fraction of LC consumers ranges from 10% in Malta to nearly 65% in Latvia. Hence, a value of λ that exceeds 0.4 may not be supported by the empirical analyses estimating the share of LC consumers.

Therefore, our model suggests that for empirically plausible parameter values, the MF fiscal stimulus is a more effective tool for stimulating the real economy than the DF regimes. This conclusion is almost the same as that derived in Galí (2020a). However, as mentioned earlier, Galí (2020a) did not show how the magnitude of the MF fiscal stimulus is affected by the degree of nominal wage stickiness in a TANK model. Unlike Galí (2020a), we could document that the finding that nominal wage stickiness and LC consumers significantly impact fiscal stimulus effectiveness is not trivial.

We also argued that regardless of fiscal regimes, nominal wages are less responsive to a fiscal stimulus in the case of sticky nominal wages.[20] Particularly, if a higher share of LC consumers is realized in the economy, boosting output through an increase in LC consumers' consumption is dampened because fiscal stimulus has a smaller impact on LC consumers' disposable income. In other words, a larger share of LC consumers generates substantial adverse income effects via the sticky wage channel of fiscal stimulus.

Furthermore, we found that this mechanism is generally independent of the fiscal authority's choice of fiscal regime. Nonetheless, our model shows that MF fiscal stimulus outperforms DF fiscal regimes even in the case of sticky nominal wages. Unlike LC consumers, Ricardian households benefit from current consumption because the MF fiscal stimulus reduces the real

[20] See also the study by Colciago (2011) for a detailed discussion.

interest rate, which significantly boosts Ricardian household consumption via the intertemporal substitution effect of the interest rate.

The novelty of our study has significant implications for fiscal policy. Thus, it is possible that in the case of sticky nominal wages, the MF fiscal stimulus is significantly reinforced by a smaller share of LC consumers. Conversely, in contrast to Galí et al. (2007), our findings suggest that for empirically plausible calibrated values, a higher share of LC consumers does not always result in a larger fiscal multiplier when the role of nominal wage stickiness is non-negligible. We address that this policy prescription generally applies to both the MF and DF regimes.

5 Sensitivity experiments

This section presents several sensitivity experiments. Galí (2020a) specified that the degree of nominal price stickiness and magnitude of a fiscal shock affect the government-spending multiplier. In this section, we look at how changes in the degree of nominal wage stickiness impact the fiscal multiplier in the TANK model, considering the degree of nominal price stickiness and the size of a fiscal shock. Section 5.1 considers how a change in the degree of nominal price stickiness affects the previous section's results. Meanwhile, Section 5.2 considers how a fiscal shock's magnitude influences the government-spending multiplier when the degree of nominal wages changes.

5.1 The degree of price stickiness

First, we consider the role of nominal price stickiness in assessing the effect of nominal wage stickiness on the fiscal multiplier under the MF and DF regimes. Indeed, Galí (2020a) found the significant impact of nominal price stickiness on the fiscal multiplier. Specifically, Galí (2020a) demonstrated that flexible nominal prices result in a lower fiscal multiplier, whereas stickier nominal prices increase the MF fiscal multiplier. However, he did not consider the role of nominal price stickiness in a TANK model with nominal wage stickiness. This subsection examines whether the impact of nominal wage stickiness on the fiscal multiplier is affected by a change in the degree of nominal price stickiness in a TANK model.

Figure 6 illustrates the fiscal multiplier under an MF regime considering several parameterizations of θ_p. In this figure, the case of $\theta_p = 0.75$ corresponds to the benchmark result

obtained in Section 4.2. A low level of nominal price stickiness results in a smaller fiscal multiplier. Consider the case of $\theta_p = 0.2$. The multiplier is smaller in the case of no LC consumers under flexible nominal wages, and this result is consistent with the finding of Galí (2020a). Even in the case of flexible nominal prices, an increased share of LC consumers results in a higher fiscal multiplier under fully flexible nominal wages. Given a share of LC consumers, an increased degree of nominal wage stickiness drives a higher fiscal multiplier.

[Figure 6 around here]

Next, consider the case of higher sticky nominal prices. Compared with a smaller degree of the parameter θ_p, sticky nominal prices magnify the multiplier for government spending. This is in line with the findings of Galí (2020a). In addition to this finding, our model demonstrates that a rise in the parameter value of λ enhances the fiscal multiplier as long as nominal wages are fully flexible. This figure reveals that in the case of $\lambda = 0.4$, the multiplier takes approximately 2.5 in the case of $\theta_p = 0.5$, whereas it takes roughly 6.0 in the case of $\theta_p = 0.75$. However, an increased degree of nominal wage stickiness lowers the fiscal multiplier for a larger value of λ. Notably, in the case of $\theta_p = 0.9$, the fiscal multiplier when $\lambda = 0$ is not responsive to a change in nominal wage rigidity.

Figure 7 illustrates the impact of the degree of nominal wage stickiness on the DF fiscal multiplier considering several parameter values of θ_p. Galí (2020a) found that in a DF regime, the fiscal multiplier is invariant regardless of the degree of nominal price stickiness. However, this paper addresses the role of nominal wage stickiness when the degree of nominal prices changes. For a smaller value of θ_w, a higher value of λ creates a larger DF fiscal multiplier. For instance, in the case of $\lambda = 0.4$, the fiscal multiplier takes a value of approximately 1.0 when $\theta_p = 0.2$. The multiplier becomes smaller as the parameter λ takes a smaller value, and this result is consistent with the finding of Galí (2020a). However, for a higher value of θ_w, an increased value of λ produces the sizable DF fiscal multiplier. When nominal wages are predominately sticky, the multiplier ranges from 1.0 to 1.5 regardless of the proportion of LC consumers. In the case of a predominately larger value of θ_p, namely, $\theta_p = 0.9$, the smaller the value of the parameter θ_w, the larger the fiscal multiplier when the share of LC consumers is higher. In this case, the fiscal multiplier exceeds 5.0 when the parameter λ takes a value of 0.4. However, an increased value of θ_w lowers the fiscal multiplier when $\theta_p = 0.9$.

[Figure 7 around here]

As long as nominal wages are fully flexible, as shown in Galí (2020a), the degree of nominal price stickiness does not affect the DF fiscal multiplier. However, when LC consumers and nominal wage stickiness coexist, the degree of nominal price stickiness significantly influences the DF fiscal multiplier. In a TANK model with nominal wage stickiness, the results of Figures 2 and 4 remain robust despite changes in the degree of nominal price stickiness.

5.2 Size of fiscal policy shock

This section examines whether the size of fiscal policy shock plays a significant role in our model. Galí (2020a) found that although the DF fiscal multiplier is unaffected by the size of the fiscal policy shock, the larger the size of the government spending shock, the greater the impact of the MF fiscal stimulus on output. This section aims to investigate whether the size of the fiscal shock significantly affects the fiscal multiplier in an NK model with the interaction of LC consumers and nominal wage stickiness under the MF and DF regimes.

Figure 8 shows the impact of a government spending shock on the MF fiscal multiplier. When the shock size is relatively small, an increased value of λ produces a larger fiscal multiplier under the MF regime in the case of fully flexible nominal wages. The fiscal authority undergoes a substantial drop in the multiplier as the degree of the parameter θ_w increases. Furthermore, if the parameter θ_w is close to unity, the difference between the multipliers of $\lambda = 0$ and $\lambda = 0.4$ is not negligible. In the case of $\delta = 0.9$, the fiscal multiplier approaches around 2.0 despite the degree of a share in LC consumers under fully flexible nominal wages. Interestingly, despite values of λ, the fiscal multiplier under the MF regime substantially increases when nominal wages are predominately sticky. For instance, although the multiplier under $\lambda = 0.4$ takes a value of approximately 5.0, that under $\lambda = 0$ achieves a value of approximately 5.5. This result is not observed in the study by Galí (2020a).

[Figure 8 around here]

Next, we consider the impact of the size of a government spending shock on the DF fiscal stimulus. Figure 9 shows the impact of varying the magnitude of a government spending shock on the DF fiscal multiplier. In the case of $\delta = 0.01$, the fiscal multiplier becomes smaller under flexible nominal wages without a share of LC consumers. This result is consistent with that

obtained by Galí (2020a). Given a share of LC consumers, the larger the degree of θ_w, the smaller the DF fiscal multiplier. Thus, as the degree of nominal wage stickiness becomes severe, the multiplier under a higher share of LC consumers decreases significantly, whereas it remains unchanged under no LC consumers.

[Figure 9 around here]

When a government spending shock becomes more prominent (i.e., $\delta = 0.9$), under flexible nominal wages, the DF fiscal multiplier does not exceed unity even with a higher share of LC consumers. Of course, as shown in Galí (2020a), the fiscal multiplier takes a smaller value in the case of no LC consumers. Even in this case, the multiplier becomes larger under a higher share of LC consumers under a DF regime. As the parameter θ_w is close to unity, the multiplier increases given a share of LC consumers.

In summary, the results shown in Figures 2 and 4 are robust to the size of a government spending shock. We argue, therefore, that the interaction between LC consumers and nominal wage stickiness should be considered when evaluating the impact of the size of a government spending shock on the fiscal multiplier in MF and DF regimes.

6 The case for a tax cut

This section investigates how the degree of nominal wage stickiness affects fiscal stimulus via tax cuts. Following Galí (2020a), we consider the lump-sum tax cut since we do not introduce a distorted taxation system in the model. Unless otherwise noted, this type of tax cut is the tax-cut multiplier in this paper. This investigation corresponds to the robustness check of our result because Galí (2020a) considered the role of a tax cut in accounting for the role of MF and DF regimes. He demonstrated that as with government spending, the difference between the multipliers of the MF and DF regimes is significant under a tax cut. In particular, Galí (2020a) found that the DF fiscal multiplier is unresponsive to changes in nominal price stickiness or the size of the fiscal shock. Section 6.1 explores the sensitivity of our results to changes in the degree of nominal price stickiness, and Section 6.2 reports the robustness results regarding the size of a tax cut shock.

6.1 Degree of nominal price stickiness

Figure 10 depicts the impact of a change in the degree of nominal price and wage rigidity on the MF tax-cut multiplier. Under flexible nominal wages, the multiplier close to zero is attained without LC consumers. This result is consistent with that of Galí (2020a). Unlike the case of Figure 2, although the multiplier increases as the proportion of LC consumers increases, an increase in nominal wage rigidity enhances the multiplier in the absence of LC consumers.

[Figure 10 around here]

When nominal prices are considerably sticky, namely, $\theta_p = 0.9$, the MF multiplier becomes around 8.0 if a higher share of LC consumers is present in an economy with fully flexible nominal wages. However, even with a higher share of LC consumers, an increase in nominal wage stickiness substantially weakens the impact of the MF fiscal stimulus on output. When nominal wages are primarily sticky, the multiplier approaches approximately 2.0 despite the value of λ.

Next, consider the case of the DF tax-cut multiplier in Figure 11. First, regardless of the degree of nominal price stickiness, the fiscal multiplier takes the value of zero in the absence of LC consumers, and this result is consistent with that of Galí (2020a). This is not a surprising result because the Ricardian households expect that the fiscal stimulus provided by current tax cuts will be offset by future tax increases, i.e., Ricardian equivalence. However, even in a DF regime, introducing LC consumers increases the fiscal multiplier. For instance, consider the case of $\lambda = 0.4$. In the case of $\theta_p = 0.2$, the multiplier is 0.4 under fully flexible nominal wages. Further, in the case of $\theta_p = 0.9$, the multiplier takes a value of 2.0 under fully flexible nominal wages.

[Figure 11 around here]

6.2 Size of a tax cut shock

This section focuses on the role of the size of a tax cut shock. Figure 12 illustrates that for the case of a smaller shock size, an increased degree of nominal wage stickiness lowers the MF fiscal multiplier in our TANK model. When $\delta = 0.9$, the fiscal multiplier ranges from 1.0 to 1.5 under fully flexible nominal wages regardless of the value of λ. Similar to government spending, an increase in nominal wages amplifies the fiscal multiplier via a tax cut. Notably, when nominal

wages are predominately sticky, as shown in Figure 8, the fiscal multiplier of a tax cut is lower than that of government spending. Thus, even when nominal wage stickiness is introduced into a TANK model, as argued by Galí (2020a), the government-spending multiplier generally dominates the tax-cut multiplier.

[Figure 12 around here]

Further, consider how the shock size affects the impact of the DF fiscal stimulus on output under a tax cut, as shown in Figure 13. This figure illustrates that regardless of the value of θ_w, the DF multiplier under LC consumers always dominates that under no LC consumers. In addition, as shown by Galí (2020a), the multiplier is zero in the case of a RANK model, namely, $\lambda = 0$. For a smaller value of δ, the multiplier under $\lambda = 0.4$ becomes 1.5 under fully flexible nominal wages. Conversely, in the case of $\delta = 0.9$, given the degree of nominal wage stickiness, the multiplier does not exceed unity regardless of the value of λ. Thus, as long as λ is not zero, an increased degree of nominal wage stickiness amplifies the DF fiscal multiplier under a tax cut. However, when the parameter θ_w exceeds 0.8, the multiplier decreases again.

[Figure 13 around here]

7 Extended analysis

This section provides several extensions of the baseline analysis. First, although we assumed that the labor union determines nominal wages in a staggered manner, we also consider the segmented labor market. Second, we implement the robustness check to determine whether the main results are affected by introducing price and wage inflation persistence. Third, we examine how the introduction of ZLB constraints affects the effectiveness of fiscal policy in our model.

7.1 Alternative labor market structure

Following Ascari et al. (2017), we introduced the labor union model that determines optimal nominal wages in a staggered manner into the benchmark model. However, if the labor market is segmented between Ricardian and LC consumers, the effect of nominal wage stickiness on the multiplier may be affected because each household can optimally choose labor hours in the

segmented market model.[21] Although Galí et al. (2007) argued how the fiscal multiplier under a labor union differs from one under a segmented market, they did not consider whether the degree of nominal wage stickiness affects the fiscal multiplier in a TANK model.

In this sensitivity experiment, following Ascari et al. (2017), we incorporate a segmented labor market into the TANK model. On the one hand, Ricardian households provide a differentiated type of labor j and can be regarded as monopolists on labor market j; on the other hand, LC consumers do not perceive their power in the labor market and supply each type of labor given the nominal wage fixed by Ricardian households. Accordingly, Ricardian households can devote their labor hours at the fixed nominal wage as many hours to the labor market required by the firms that consider the part of labor hours supplied by LC consumers.

[Figure 14 around here]

Figure 14 shows how the segmented market assumption affects our main results. We found that under a DF regime, the specification of the labor market does not qualitatively influence the government-spending multiplier. Given a degree of nominal wage stickiness, we may have a larger government-spending multiplier in the segmented market model than in the labor union model. This figure shows that the fiscal multiplier for MF and DF regimes becomes larger in the benchmark model than in the segmented market model.

The intuition of the result is as follows. Consider the case for an MF regime. In the case of flexible nominal wages, an increase in government spending leads to an increase in wage and price inflation, causing a rise in the real wages. In the segmented market model, an increase in the real wages induces a change in the Ricardian households' intratemporal substitution effect between consumption and labor supply, thereby increasing their labor supply. In contrast, a real interest rate decline also boosts Ricardian households' consumption under sticky nominal wages, dampening the above substitution effect. Under a segmented market model, the total impact of these two channels renders the fiscal multiplier under the MF regime unaffected by the degree of nominal wage stickiness.

Conversely, a benchmark model with fully flexible nominal wages attains a larger fiscal multiplier since a rise in real wages boosts LC consumers' consumption. Indeed, Figure 14

[21] We note that there is no difference in nominal wages between Ricardian and LC consumers even in the segmented market model.

shows that under an MF regime, a substantial difference exists between both models in the case of fully flexible nominal wages. An increased degree of nominal wages reduces the fiscal multiplier, which is larger in a benchmark model than in a segmented market model. Although a similar discussion basically holds for the case of the DF regime, the difference between the two models is small under this regime in contrast to an MF regime. To sum up, our main message remains unaffected by introducing an alternative labor market specification.

7.2 Degree of wage and inflation inertia

Next, we consider the role of plausible estimated value of nominal wage and price inflation persistence when considering the effect of fiscal policy on output. We abstract from endogenous price and wage inflation persistence in the benchmark model. However, several studies discuss the role of the inertial behavior of price and inflation dynamics (Christiano et al., 2005, Smets and Wouters, 2003, 2007). Thus, we may require a more general specification regarding price and wage inflation dynamics. In this subsection, therefore, we check whether the fiscal multiplier is affected by introducing endogenous wage and price inflation persistence, allowing us to generalize fiscal policy's effect on price and wage inflation. We adopt the indexation hypothesis (Bodenstein and Zhao, 2019, Christiano et al., 2005, Smets and Wouters, 2003, 2007, Woodford, 2003) to investigate the role of endogenous price and wage inflation persistence. Following Woodford (2003), we derive the following hybrid price and wage NKPCs:

$$\pi_t^p - \iota_p \pi_{t-1}^p = \beta(\pi_{t+1}^p - \iota_p \pi_t^p) - \delta_p \mu_t^p, \tag{41}$$

$$\pi_t^w - \iota_w \pi_{t-1}^w = \beta(\pi_{t+1}^w - \iota_w \pi_t^w) - \delta_w \mu_t^w, \tag{42}$$

where ι_p and ι_w denote the degree of price and wage inflation persistence. Based on the empirical results obtained by Smets and Wouters (2007) and Bodenstein and Zhao (2019), we set the empirically plausible values of ι_p and ι_w to 0.24 and 0.58, respectively.

[Table 1 around here]

Table 1 shows the government-spending multipliers when price and wage inflation persistence are incorporated into the model. In contrast to no price and wage inflation inertia, the government-spending multiplier under MF and DF regimes slightly depends on only wage inflation persistence, but we also found its negligible effect on the fiscal multiplier. Thus, our main results are unaffected by the introduction of price and wage inflation persistence.

7.3 The effect of the ZLB

We also explore the role of sticky nominal wages in evaluating the effect of fiscal stimulus during the liquidity trap.[22] As in the case considered by Galí (2020a), the ZLB takes the form of $\hat{i}_t \geq \log \beta$ for all t. The natural interest rate $\hat{\rho}_t$ temporarily drops the negative value up to period T. In this paper, we consider the experiment that $\hat{\rho}_t = -\gamma < \log \beta$ for $t = 0, 1, 2, ...T$ and $\hat{\rho}_t = 0$ for $t = T + 1, T + 2, ...$

As noted earlier, the money demand function holds as long as the nominal interest rate does not reach its lower bound. Unlike Galí (2020a), in our model, the money demand function holds for both Ricardian and non-Ricardian consumers. Therefore, we must consider the effect of the ZLB constraints on the money demand function for each consumer. Specifically, when the ZLB constraints are binding, the money demand function should be replaced with the following complementarity slackness condition:

$$(\hat{i}_t - \log \beta)(\hat{l}_{k,t} - \eta_c \hat{C}_{k,t} - \eta_i \hat{i}_t) = 0, \tag{43}$$

for all t and for $k = o, r$. Moreover, following Galí (2020a), we consider the case of both DF regimes and no fiscal response. As the central bank follows the simple Taylor rule in these cases, the ZLB constraints become $\hat{i}_t = \max(-\log \beta, \hat{i}_t^*)$. Here, $\hat{i}_t^*$ denotes the nominal interest rate suggested by the Taylor rule (33). Finally, in this exercise, a sizable decline in aggregate demand causes a liquidity trap situation. More precisely, following Galí (2020a), we assume that negative aggregate demand shocks last from period 1 to period 6.

[Figure 15 around here]

[22] We use the log-linearized system in this simulation. One may think that using the log-linearized system leads to concerns regarding lack of capturing the nonlinear effect of the ZLB or accuracy of the model solution. For instance, Horvath, Kaszab, Marsal, and Rabitsch (2020) argued the importance of the nonlinear effect of fiscal policies on the real economy in a model with the ZLB. Nevertheless, we use the log-linearized system in this sensitivity check for the following reasons. First, using the log-linearized model allows us to directly compare our results with those obtained by Galí (2020a). Second, as our model is deterministic, we do not experience the uncertainty effect associated with the ZLB (Adam and Billi, 2006, 2007). Third, we do not concentrate on the case of the nonlinear dynamics, such as the risk premium of asset prices or default risks. This is an interesting and important topic, but it is beyond the scope of the paper. We would like to consider the nonlinear effect of the ZLB on fiscal policy in future research.

Figure 15 illustrates the dynamic effects of increased government spending on output in an economy with the ZLB. In the case of no response, a decline in output is larger under flexible nominal wages than under sticky nominal wages. First, consider the case of the MF regime. As argued by Galí (2020a), the presence of the ZLB dampens the effect of an MF fiscal stimulus in our model. When nominal wages are sticky, the effect of government spending on output is larger in an economy with LC consumers than in one without. Under flexible nominal wages, the effect of government spending on output is almost unaffected by the presence of LC consumers. Next, we examine the effect of government expenditure on output under the DF regime. Under this regime, we obtain a similar result of the case for an MF regime. Summing up, as argued by Galí (2020a), our model shows that introducing the ZLB is likely to lower the government-spending multiplier for an MF regime. In particular, when nominal wages are sticky, the fiscal authority can achieve a higher output level in the case of $\lambda = 0.25$ than in the case of no LC consumers.

8 Conclusions

This paper examined how a change in nominal wage stickiness influences the effect of the fiscal stimulus via government spending in the TANK model. When evaluating the fiscal multiplier under both MF and DF regimes, we assessed the significant role of nominal wage rigidity. Although previous research has primarily focused on the effectiveness of fiscal policy in the standard NK model, the novelty of this paper is that it demonstrates how the degree of nominal wage stickiness affects the fiscal multiplier in the tractable TANK model.

We summarize our main findings as follows. First, under fully flexible nominal wages, an increased share of LC consumers amplifies the fiscal multiplier under the MF and DF regimes. Second, in the presence of a sizable share of LC consumers, an increased degree of nominal wages decreases the MF fiscal multiplier. Third, in our model, the fiscal multiplier under an MF regime outperforms that under a DF regime. Fourth, in the case of MF and DF regimes, an increased share of LC consumers increases the fiscal multiplier under fiscal stimulus via a tax cut given the degree of nominal wage stickiness. Finally, the degree of nominal price stickiness and the size of government spending are important factors in our model. This study indicates that for empirically plausible parameter values, the MF fiscal stimulus becomes a more effective tool for stimulating the real economy than the DF regime.

Our study has certain limitations. Although we consider the effect of fiscal policy in an economy without the implementation lag of government spending, whether our main results are affected by such a lag is worth investigating. Additionally, we abstracted from the introduction of capital accumulation. Therefore, we can consider the effect of an MF fiscal stimulus in a medium-scale dynamic stochastic general equilibrium model. Moreover, to keep the model as tractable as possible, this study examined the role of an MF fiscal stimulus in a simple TANK model. However, several studies focus on the effect of the fiscal stimulus on output in a generalized HANK model. For instance, whether the introduction of household heterogeneity significantly affects the impact of an MF fiscal stimulus on output in a HANK model should be explored. These issues should be considered in future research.

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Figure 1: Dynamic effect of government-spending multiplier under money-financed fiscal stimulus

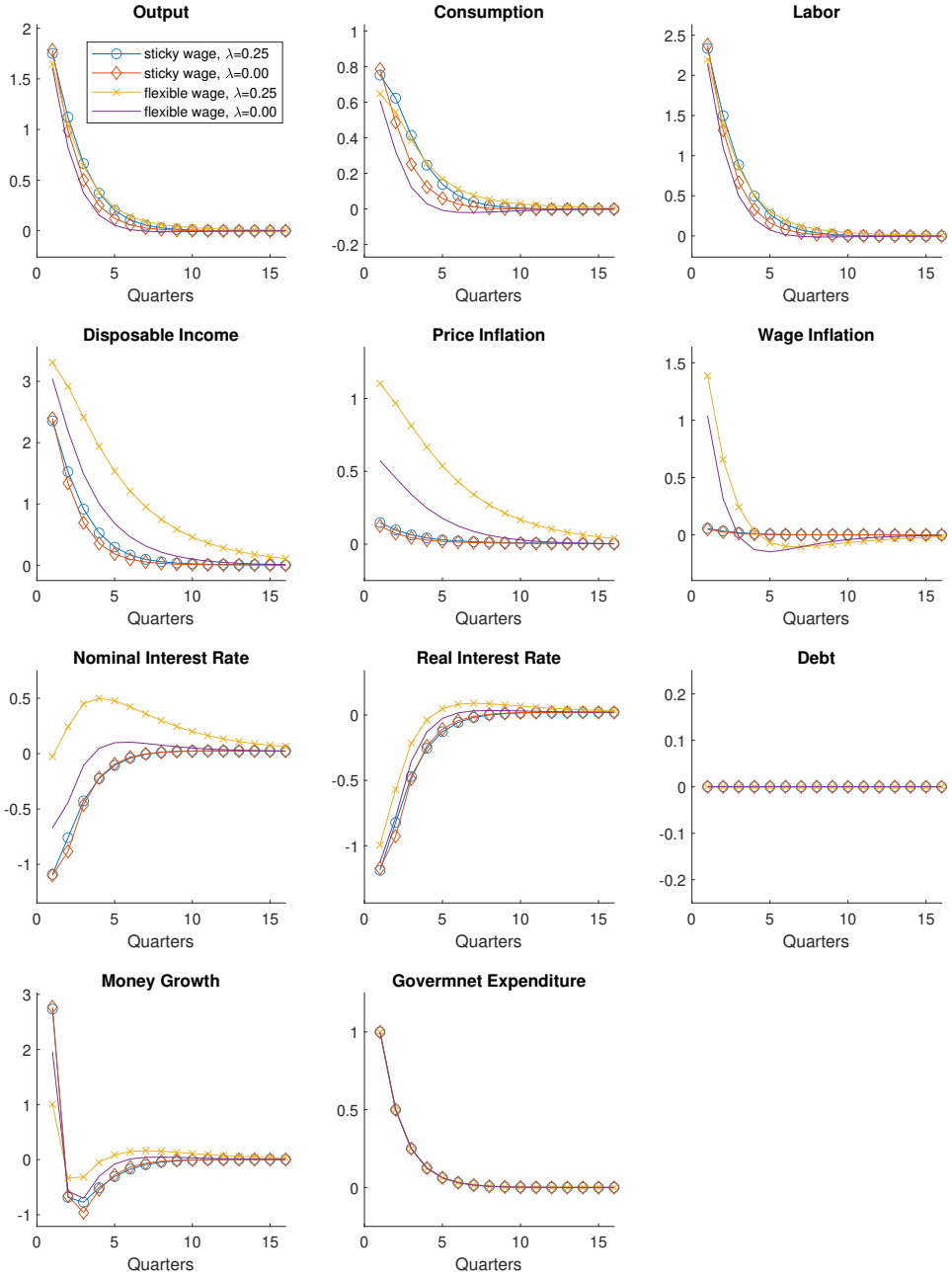

Figure 2: Government-spending multiplier under money-financed fiscal stimulus: Role of nominal wage rigidity

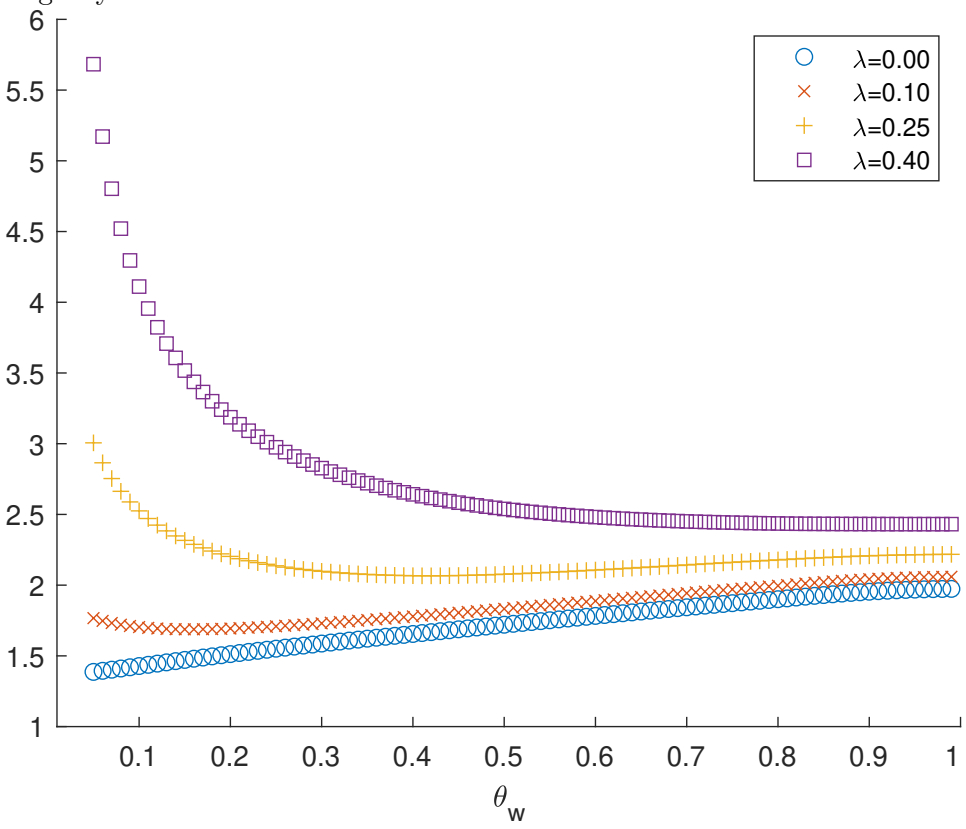

Figure 3: Dynamic effect of government-spending multiplier under debt-financed fiscal stimulus

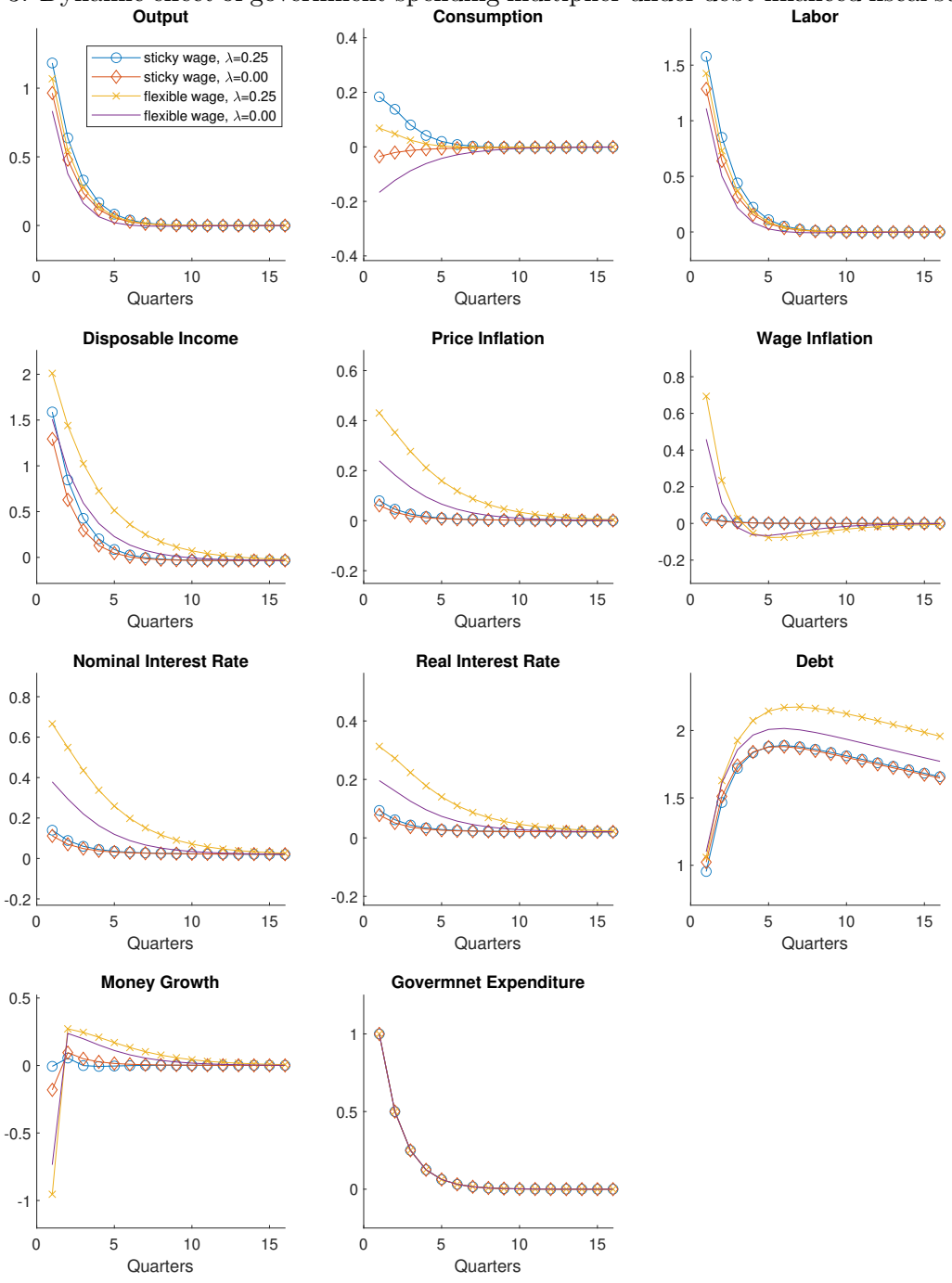

Figure 4: Government-spending multiplier under debt-financed fiscal stimulus: Role of nominal wage rigidity

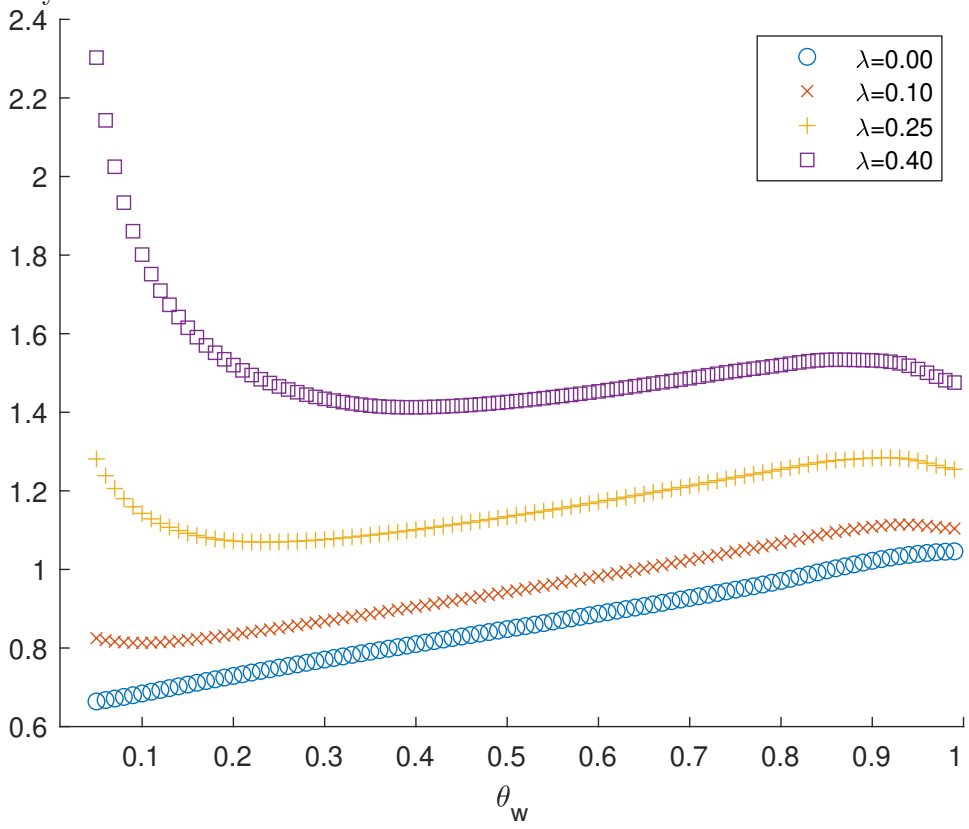

Figure 5: Comparison of government-spending multiplier between MF and DF regimes

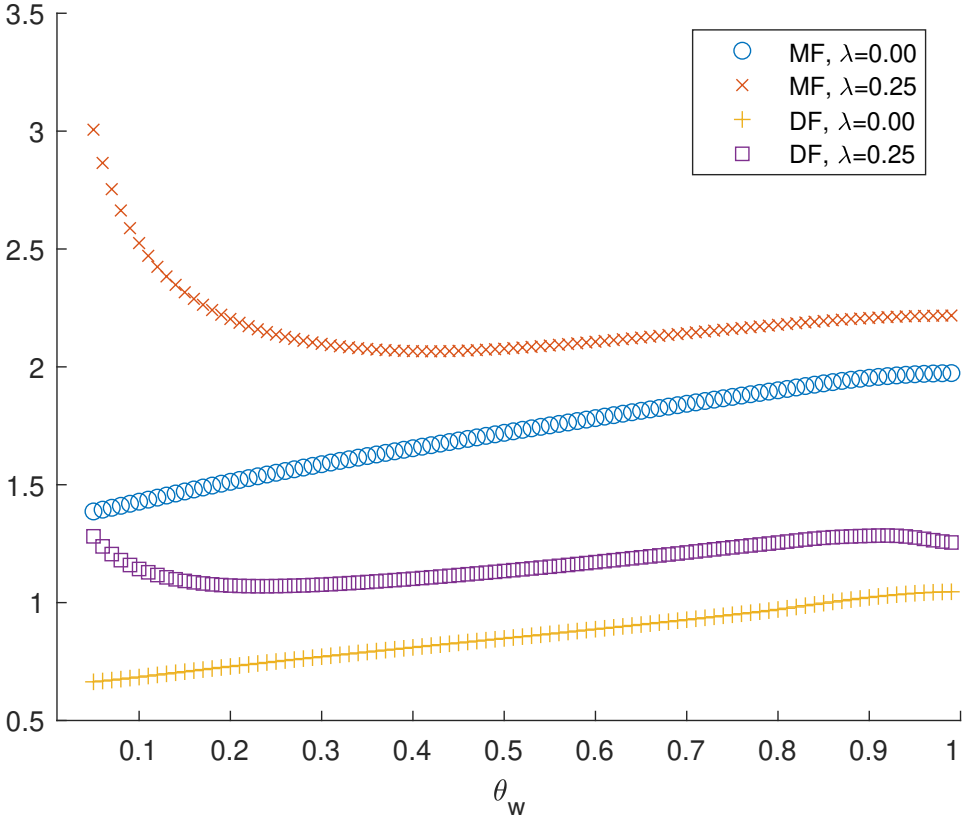

Figure 6: Government-spending multiplier under money-financed regime: Role of price stickiness

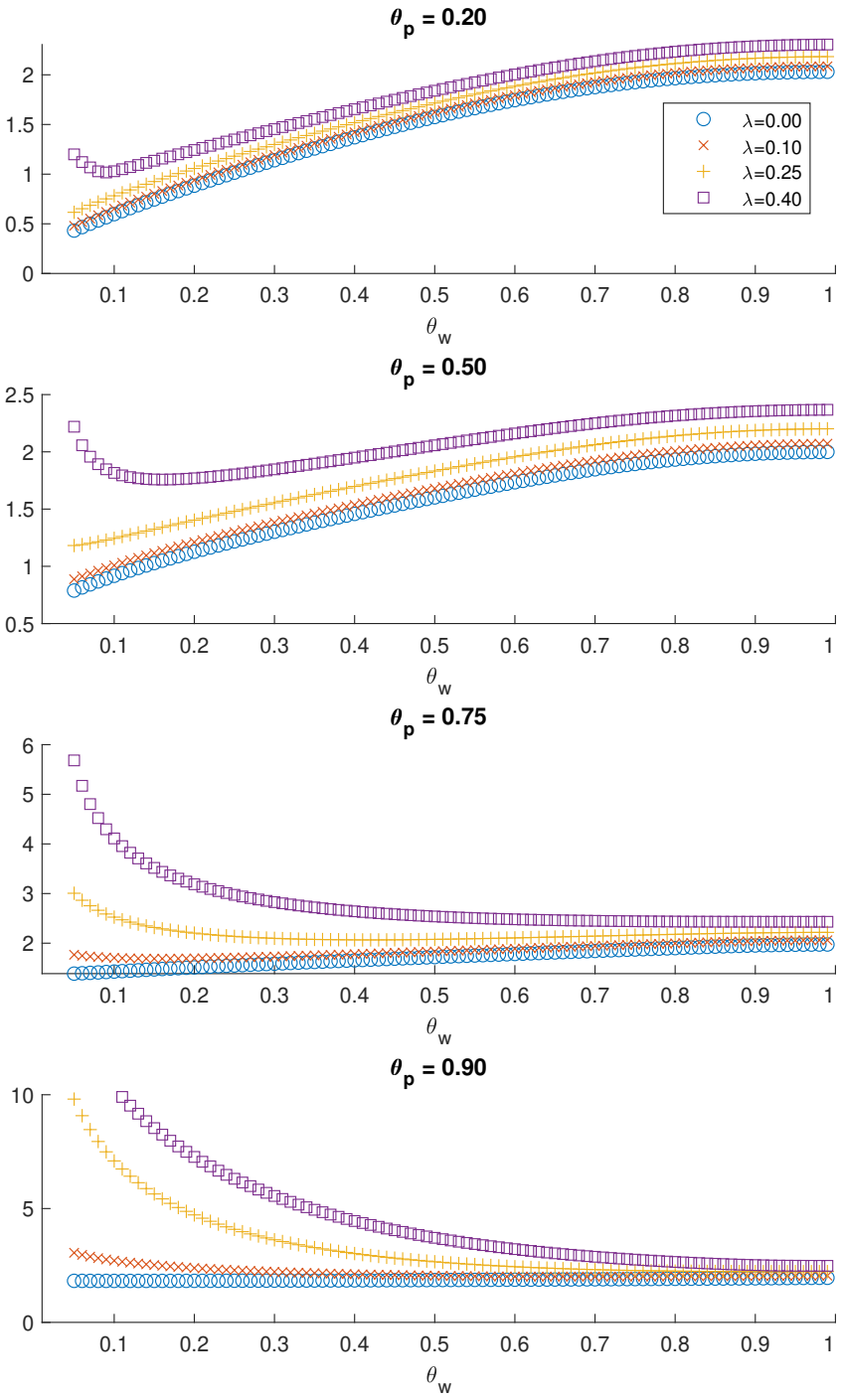

Figure 7: Government-spending multiplier under debt-financed regime: Role of price stickiness

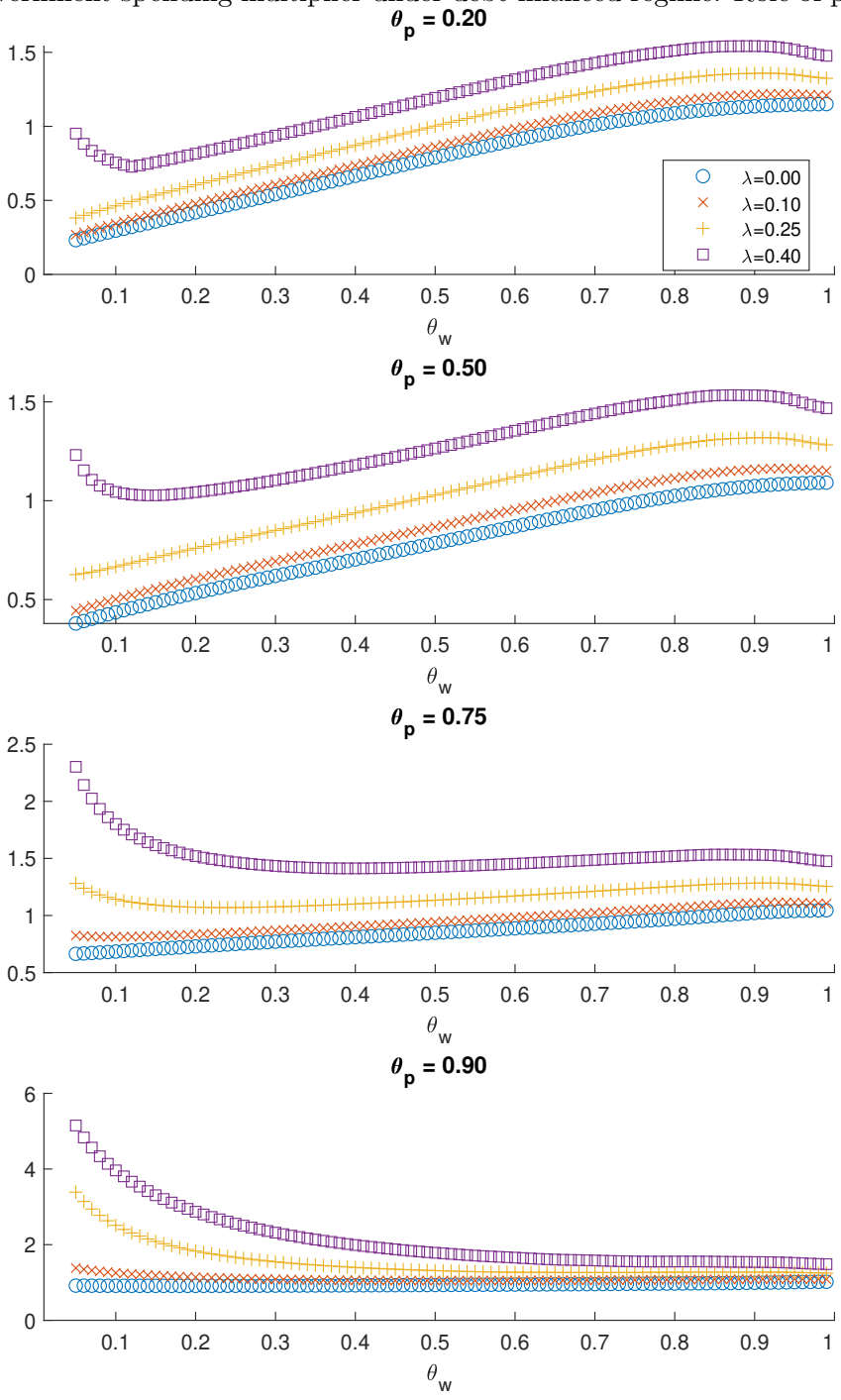

Figure 8: Government-spending multiplier under money-financed regime: Size of fiscal shocks

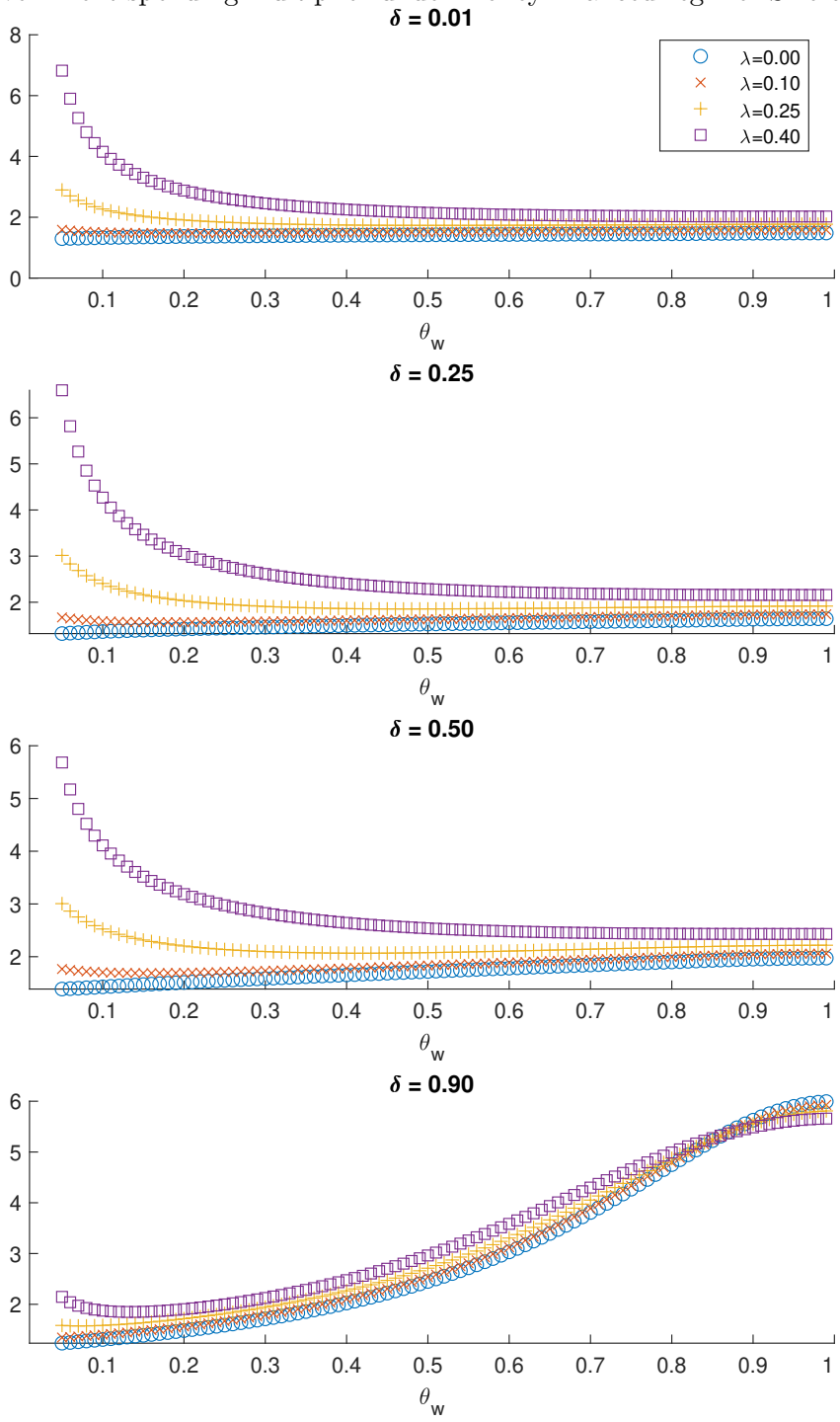

Figure 9: Government-spending multiplier under debt-financed regime: Size of fiscal shocks

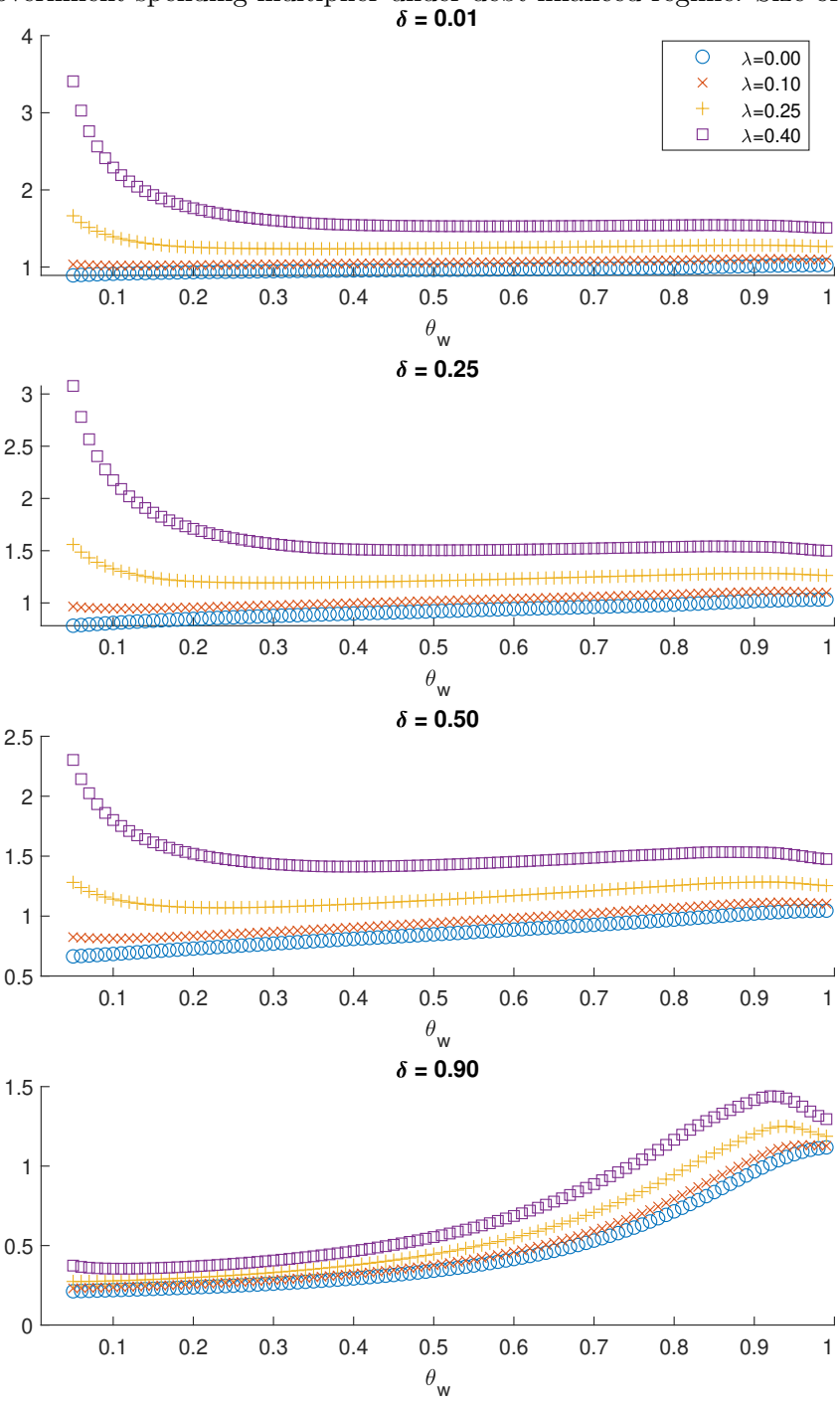

Figure 10: Tax-cut multiplier under money-financed regime: Role of price stickiness

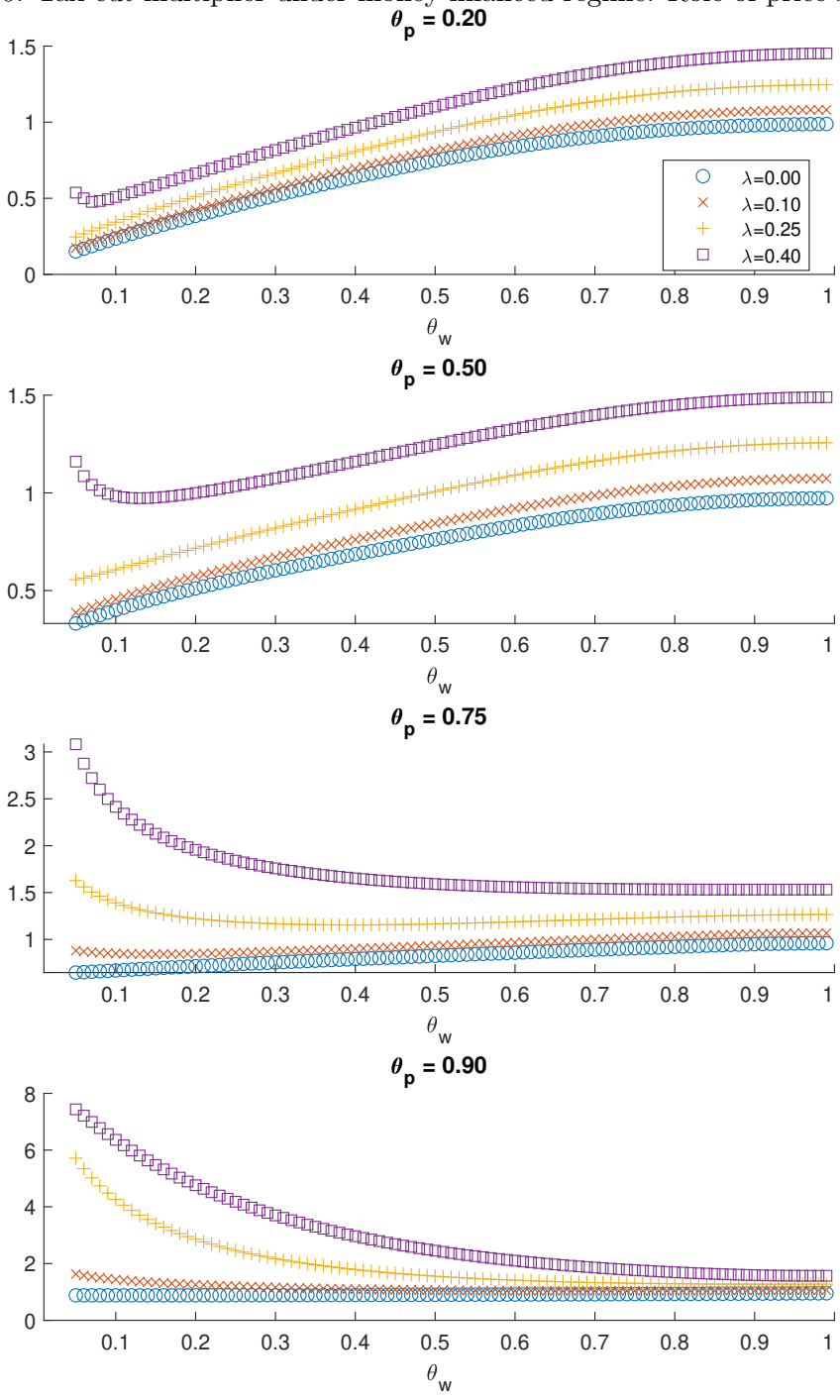

Figure 11: Tax-cut multiplier under debt-financed regime: Role of price stickiness

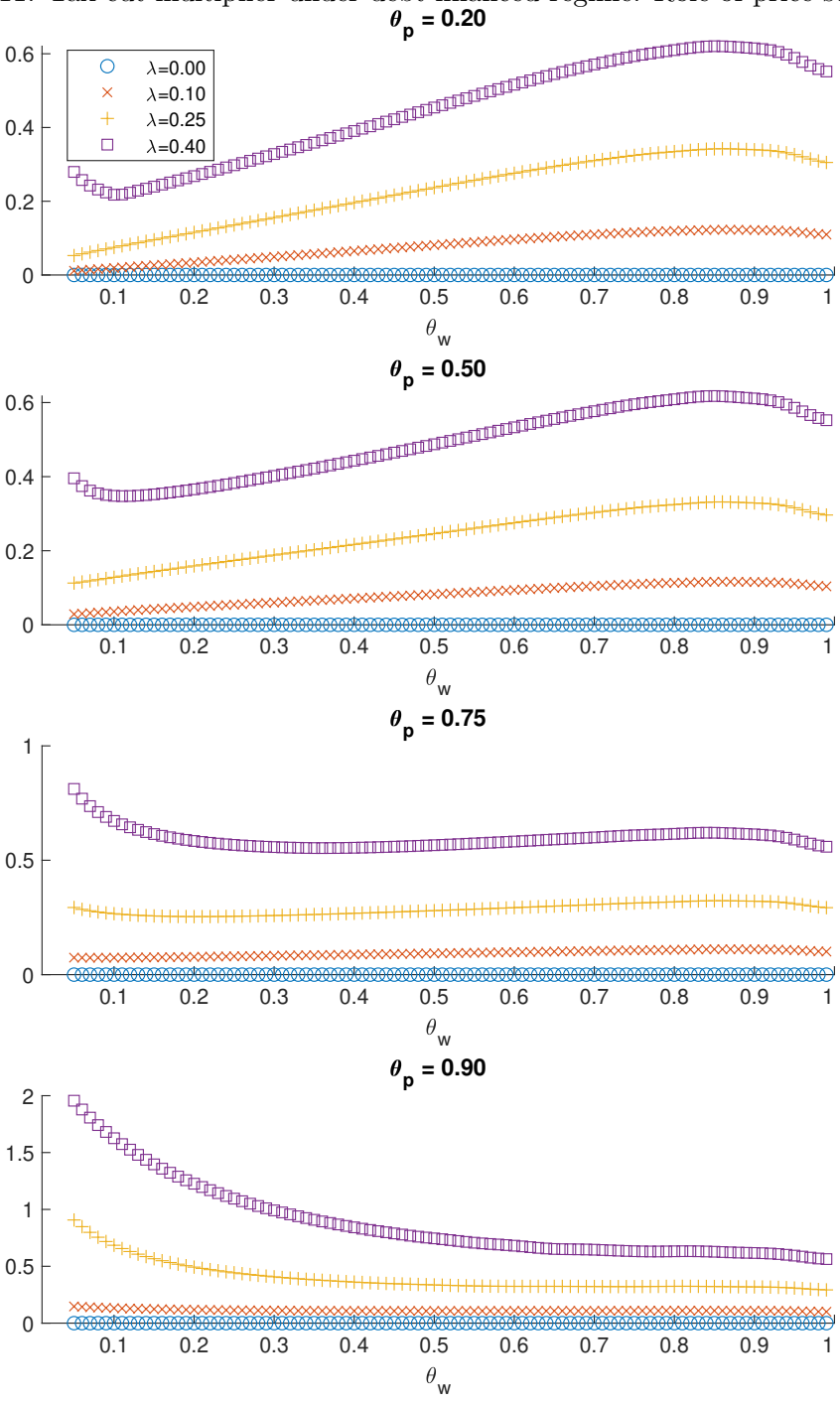

Figure 12: Tax-cut multiplier under money-financed regime: Size of fiscal shocks

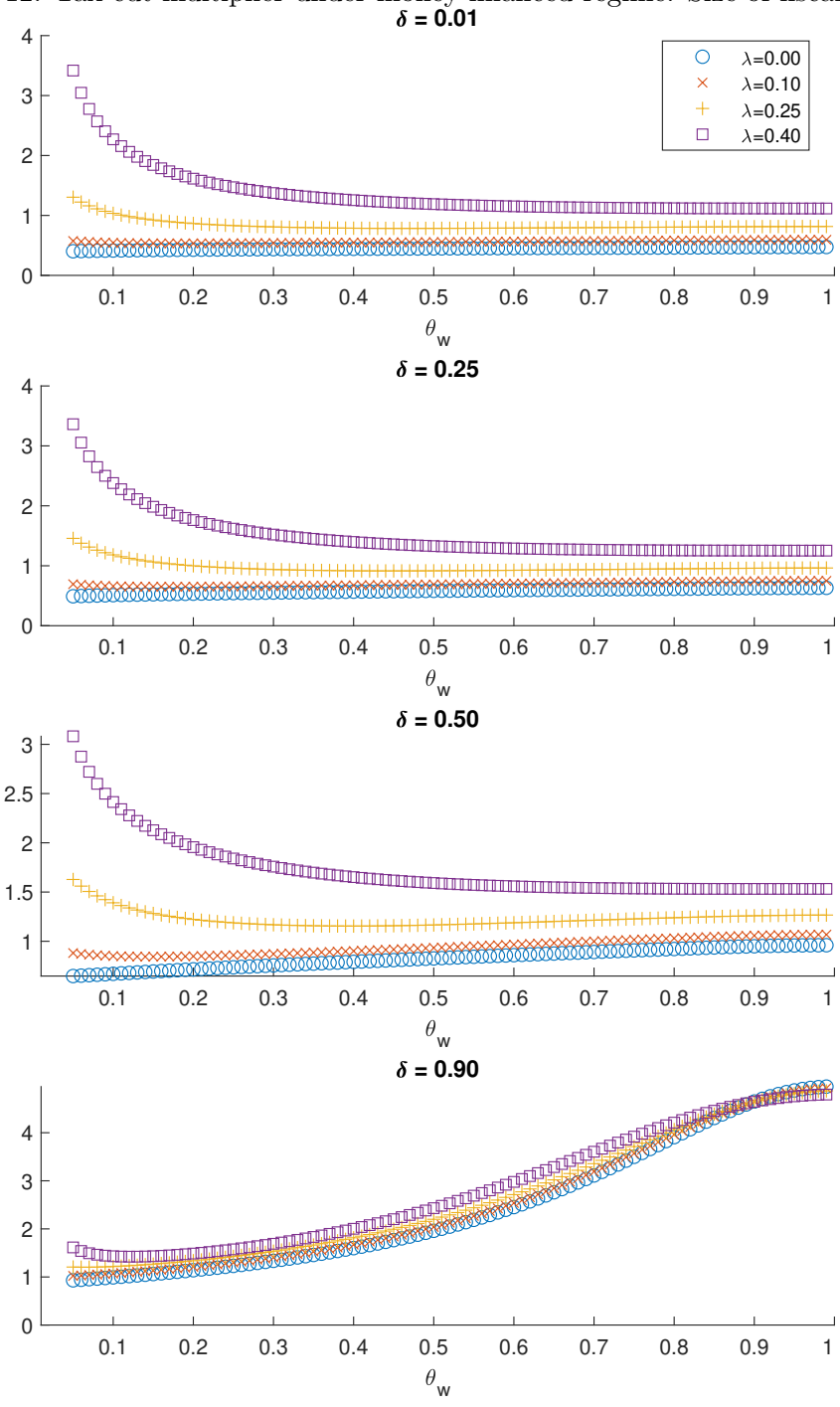

Figure 13: Tax-cut multiplier under debt-financed regime: Size of fiscal shocks

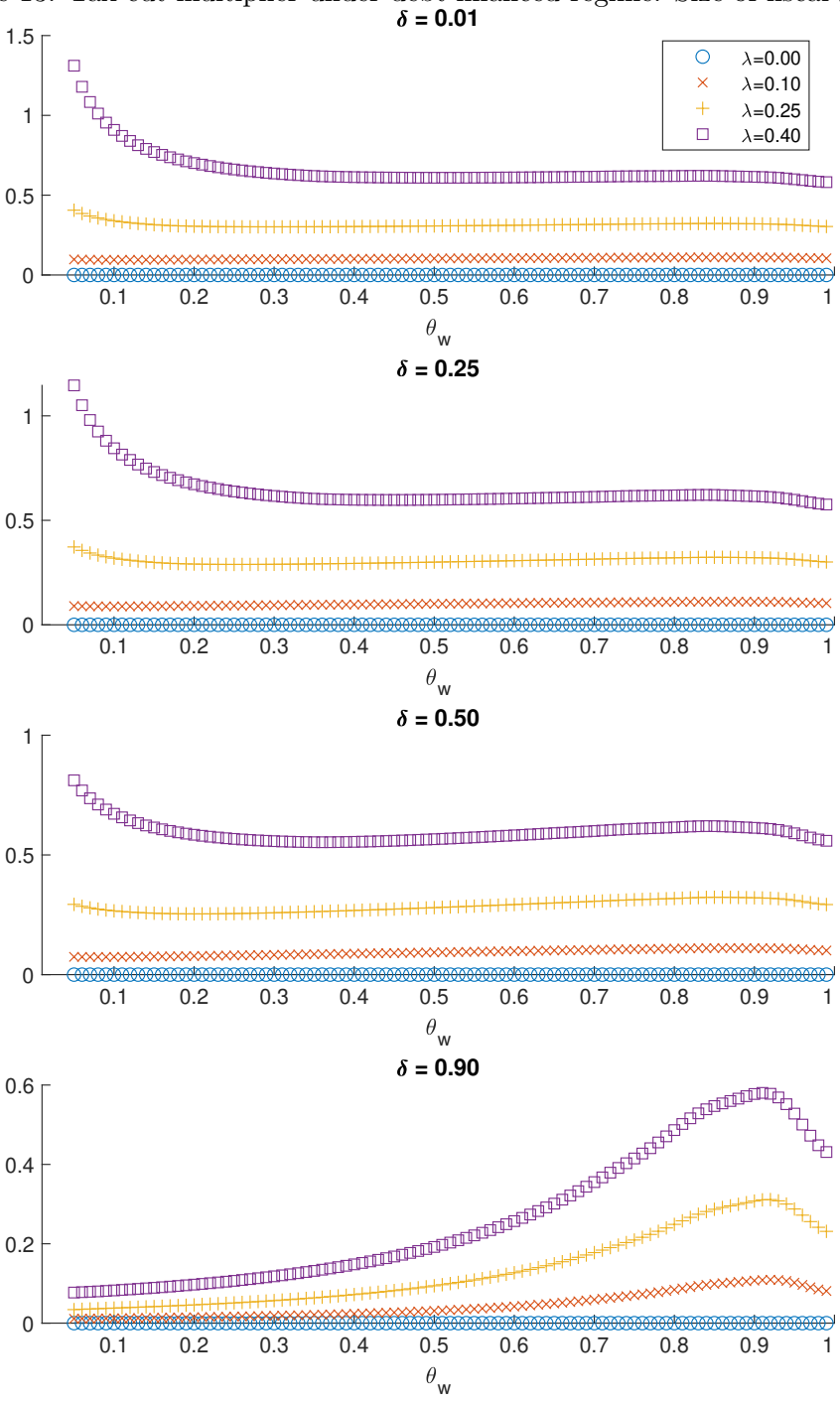

Figure 14: Government-spending multiplier in a model with segmented labor market

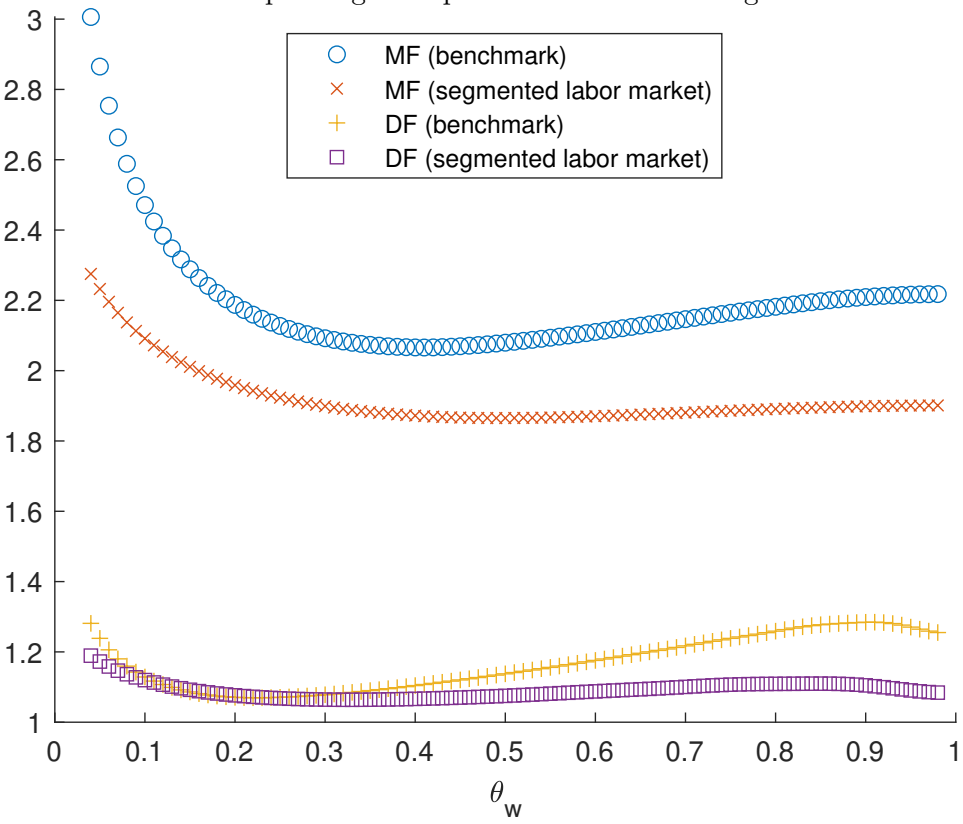

Figure 15: Dynamic effects of increased government spending on output in a liquidity trap

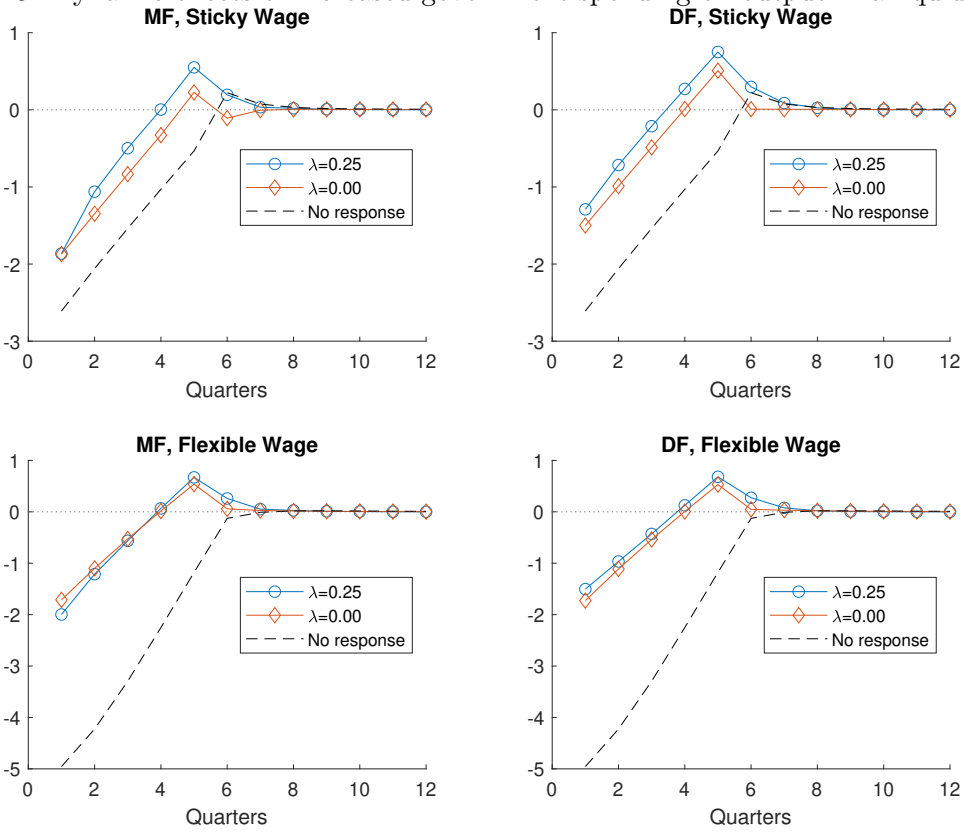

Table 1: Effect of price and wage inflation inertia on government-spending multiplier

	Money-finance (MF)	Debt-finance (DF)
(i) No inertia	2.16	1.23
(ii) Only price inflation inertia	2.15	1.23
(iii) Only wage inflation inertia	2.09	1.17
(iv) Price and wage inflation inertia	2.07	1.17

(Note) No inertia implies $\iota_p = 0$ and $\iota_w = 0$. Only price inflation inertia implies $\iota_p = 0.24$ and $\iota_w = 0$. Only wage inflation inertia denotes $\iota_p = 0$ and $\iota_w = 0.58$. Finally, price and wage inflation inertia indicates $\iota_p = 0.24$ and $\iota_w = 0.58$.