The neo-Fisherian effect in a new Keynesian model with real money balances

Ida, Daisuke

29 March 2024

The neo-Fisherian effect in a new Keynesian model with real money balances*

Daisuke Ida†[a,b]

[a]Faculty of Economics, Momoyama Gakuin University
[b]Research Fellow, Graduate School of Economics, Kobe University

May 16, 2025

Abstract

This study explores how the real money balance effect (RMBE) affects the neo-Fisherian effect (NFE) in a standard new Keynesian (NK) model. Our main findings are summarized as follows. First, the presence of the RMBE can partly explain the occurrence of the NFE. Furthermore, increasing the nonseparability parameter in the utility function magnifies the nominal interest rate's positive response to a persistent inflation target shock. Second, the degree of nominal price stickiness is important in explaining how the RMBE amplifies the NFE. Third, introducing inflation inertia into the Phillips curve eliminates the NFE.

JEL codes: E52; E58

Keywords: Neo-Fisherian effect; New Keynesian model; Real money balances; Interest rates; Inflation

---

*I would like to thank the Editor Marcelo Bianconi and an anonymous referee for helpful comments and suggestions. I also thank Mitsuhiro Okano for his useful comments and suggestions. This study was supported by JSPS KAKENHI Grant Numbers JP20K01784, JP23K01410, and JP24K04971. All remaining errors are my own.

†Faculty of Economics, Momoyama Gakuin University, 1-1, Manabino, Izumi, Osaka 594-1198, Japan. Tel.: +81-725-92-6134. E-mail: ida-dai@andrew.ac.jp

1 Introduction

Does an increase in the central bank's target inflation induce a rise in the nominal interest rate? This question has recently become crucial for the effectiveness of monetary policy in advanced economies. Central banks in advanced countries have maintained lower interest rates to combat deflationary risks. Several studies have argued that the central bank should raise the nominal interest rate when inflation becomes too low (Cochrane, 2016, Williamson, 2019). Many central banks attempt to raise nominal interest rates to combat inflationary risks. For instance, since 2022, the Federal Reserve Board in the United States has steadily raised the Federal Funds rate to suppress the inflationary pressures in the real economy. In other words, recent evidence suggests that the nominal interest rate rises in response to inflationary pressure, showing a positive relationship between inflation and the nominal interest rate.[1]

Standard macroeconomic theory posits that the inflation rate would decline after the nominal interest rate rises. This prediction is based on the standard monetary transmission mechanism that a monetary tightening shock prevents an increase in the inflation rate. Conversely, the neo-Fisherian hypothesis indicates a positive comovement between the nominal interest rate and inflation in the short run (Airaudo and Hajdini, 2023, Garín, Lester and Sims, 2018, Uribe, 2022). This hypothesis implies that a persistent and transitory rise in the interest rate is related to an increase in the inflation rate. How should we reconcile this tension between theoretical and empirical claims?

This study focuses on the role of the real money balance channel in accounting for this contradiction. Indeed, past research addressed how monetary aggregates impact the real economy (Belongia and Ireland, 2022, Kurozumi, 2006, Ida, 2023, Woodford, 2003). According to the real money balance channel, a change in money balances affects the aggregate demand via the monetary policy's demand and supply channels. For instance, an increase in real money balances increases output if the IS curve depends on real money balances (Pigou, 1943). Real money balances affect the IS curve if the nonseparable utility function between consumption and real money balances is assumed (Woodford, 2003). In this case, real money balances

[1] This study does not consider the price puzzle problem. The price puzzle means that the inflation rate increases with monetary contraction in the empirical studies (Sims, 1992). See Florio (2018), Hanson (2004) and Ida (2024) for a detailed discussion about the role of the price puzzle phenomenon, which is that monetary tightening causes an increase in inflation.

also affect the inflation rate through the aggregate supply curve (Woodford, 2003). These mechanisms are called the real money balance effect (RMBE). Several recent studies argue the empirical justification of the RMBE (Benchimol and Fourçans, 2012, Dorich, 2009, Favara and Giordani, 2009, Poilly, 2010, Serletis and Xu, 2020). Nevertheless, how the RMBE affects the neo-Fisherian effect (NFE) occurrence is unclear. Examining the relationship between inflation and the nominal interest rate is essential.

The above arguments motivate this study. According to Garín et al. (2018), a rise in the central bank's target inflation rate increases the nominal interest rate in the short run. Additionally, the money demand function generally posits that an increase in the nominal interest rate causes a reduction in the money aggregate, provided the nominal interest rate does not reach the zero-lower bound floor. Under the RMBE, reducing real money balances boosts the inflation rate through an aggregate supply relationship in a sticky price model (Ida, 2023, Woodford, 2003). We manifest how the RMBE plays a significant role in explaining this study's NFE.

As Kurozumi (2006) and Woodford (2003) suggested, the degree of nonseparability between consumption and real money balances in the household utility function significantly impacts the RMBE's strength.[2] Dorich (2009) used the standard NK framework to empirically show the larger value of the nonseparability parameter in the US economy.[3] Benchimol and Fourçans (2012) found that the dynamic stochastic general equilibrium model that assumes the nonseparability between money and consumption can capture the monetary policy transmission in the Eurozone. Moreover, Williamson (2019) posited the importance of the money aggregate in explaining the relationship between inflation and the nominal interest rate in the Volker era, arguing that movements in inflation and nominal interest rates during the Volker era are consistent with neo-Fisherianism. To our knowledge, however, no past studies have examined whether the RMBE causes the NFE.

The study's main findings are as follows. First, the presence of the RMBE can explain NFE occurrences within empirically plausible values of the nonseparability parameter. Furthermore,

[2]Several studies have also argued the statistical significance of the nonseparability assumption (McKnight and Mihailov, 2015, Poilly, 2010).

[3]He argued that we may obtain the larger value of this parameter in the empirical investigation when considering that the definition of money is different: monetary base versus M2. See Dorich (2009) for a detailed discussion.

a higher nonseparability parameter value magnifies the nominal interest rate's positive response to a persistent inflation target shock. Second, the degree of nominal price stickiness is important in explaining the NFE's amplification due to the RMBE. Third, as Garín et al. (2018) showed, introducing inflation inertia into the Phillips curve eliminates the NFE even if we permit strong RMBE in the model.

These findings have the following intuition and policy implications. Given the degree of nominal price stickiness, a larger value of the nonseparability parameter reinforces the RMBE, causing inflation to rise via the new Keynesian Phillips curve (NKPC) (Woodford, 2003). If this channel dominates the traditional interest channel, a persistent inflation target shock increases inflation and the nominal interest rate under the strong RMBE. Provided that nominal prices are not predominantly sticky, a larger value of the nonseparability parameter generates a larger NFE. Conversely, when nominal prices are fully sticky, the occurrence of the NFE does not depend on the value of the nonseparability parameter. Thus, this paper addresses the fact that the presence of the RMBE causes a stronger NFE than the standard NK model.

Our study makes the following contributions. This paper is mainly related to Garín et al. (2018), which showed how the NFE occurs in the textbook NK model; however, our study differs in the following point. To consider the NFE, we address the role of the RMBE captured by the nonseparability parameter; specifically, increasing the value of this parameter amplifies the NFE. When the empirically plausible value of the nonseparability parameter is chosen, the NFE significantly emerges. Thus, unlike Garín et al. (2018), we emphasize the interaction between NFE and RMBE.[4]

Our study is also related to Ali and Qureshi (2022), who examined the role of the cost channel in accounting for the NFE. Like our study, they showed that the NFE arises when the cost channel matters; however, we highlight the difference between the cost channel and the RMBE. The former effect indicates that an increase in the nominal interest rate generates inflation via a rise in the firm's working capital (Ravenna and Walsh, 2006). According to Dorich (2009) and Woodford (2003), the latter effect works as follows. An increase in the nominal interest rate reduces the demand for money, which leads to a decline in the marginal

[4]We assume that the central bank sets the nominal interest rate in response to an inflation target shock. Conversely, Ali and Qureshi (2022) presumed that the central bank sets the nominal interest rate by following the standard Taylor rule.

utility of consumption, increasing the real wage via the labor supply condition. An increase in the real wage pushes the real marginal cost up, increasing inflation. We show that how the NFE effect occurs depends on the degree of the nonseparability between consumption and real money balances. As noted, several studies empirically supported this channel. We address how the RMBE interacts with the NFE, demonstrating that the presence of the RMBE significantly amplifies the NFE.

This study is also related to the following research. Bilbiie (2022) examined the NFE in the standard NK model with a liquidity trap. In comparison, we focus on how real money balances affect the impact of an inflation target shock on the nominal interest rate without assuming a liquidity trap. Moreover, Kurozumi (2006) focused on the determinacy properties in an NK model with real money balances; however, they did not consider how the RMBE generates the NFE. Airaudo and Hajdini (2023) examined the role of wealth effects in accounting for the occurrence of the NFE, focusing on the nonseparable utility between consumption and the labor supply; however, they did not investigate how the RMBE induces the NFE.

The remainder of this paper is organized as follows. Section 2 describes the standard NK model with the RMBE and explains this paper's parameter values. Section 3 summarizes our main findings. Following Galí and Gertler (1999), Section 4 introduces the lagged inflation rate by assuming the rule-of-thumb hypothesis in the NK model. Section 5 presents some policy implications, and Section 6 briefly concludes.

2 The NK model with real money balances

This section explains the standard NK model with real money balances. Following Woodford (2003), Section 2.1 provides the NK model's description with real money balances. Section 2.2 then describes the deep parameters used in this study.

2.1 Model description

Based on Woodford (2003), our model's structure is summarized as follows.[5] Subject to an intertemporal budget constraint, households maximize their utility function, comprising consumption, real money balances, and labor supply. More specifically, the model is constructed

[5]See Chapter 4 in Woodford (2003) for a detailed discussion about an NK model used in this paper.

on the end-of-period timing of the household's money holdings.[6] This paper specifies money in the utility function. We assume the utility function's nonseparability between consumption and real money balances. Firms facing a monopolistically competitive environment set their optimal prices under Calvo (1983)'s nominal price rigidity. Following Garín et al. (2018), the central bank manipulates the nominal interest rate to satisfy its inflation target. Consequently, except for the monetary policy specification, the model comprises three equations: a dynamic IS equation, an NKPC, and a money demand function. Unless otherwise noted, the lowercase variable represents a log-deviation from the steady state.

The first equation, a dynamic IS curve derived from intertemporal optimal household conditions, is given by

$$x_t = E_t x_{t+1} - \sigma^{-1}(r_t - E_t \pi_{t+1} - r_t^n) - \sigma^{-1}\chi(E_t m_{t+1} - m_t), \tag{1}$$

where x_t is the output gap, π_t is the inflation rate, r_t is the nominal interest rate, and m_t denotes real money balances. r_t^n denotes the natural rate of interest that stands for the real interest rate in the flexible price equilibrium. E_t is the expectations operator conditional on the information about period t. The parameters σ and χ denote the constant relative risk aversion coefficient and the degree of nonseparability between consumption and real money balances in the utility function, respectively.[7] In the case of $\chi > 0$, a marginal utility of consumption increases with a marginal increase in real money balances. In contrast to the standard NK model, including the nonseparable utility function results in adding a third term to the IS curve (Woodford, 2003). An expected change in real money balances impacts the current output gap; notice that the final term in the IS curve disappears when the separable utility function is assumed.

The second equation is an NKPC derived from the optimal condition of monopolistic competitors' firms and Calvo (1983) type nominal price rigidities. The NKPC is given by

$$\pi_t = \beta E_t \pi_{t+1} + \lambda(\sigma + \varphi)x_t - \lambda\chi m_t, \tag{2}$$

where the slope of the NKPC is given by

$$\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta}. \tag{3}$$

[6]See Kurozumi (2006) for the role of other specifications of the timing of household's money holding in the standard NK model.

[7]This paper assumes that $\chi \geq 0$. Benhabib, Schmitt-Grohé and Uribe (2001) consider the case of $\chi < 0$.

Parameter θ denotes the Calvo lottery, representing the degree of nominal price rigidity. φ denotes the inverse of Frisch elasticity. When the utility function cannot be separated from consumption and real balances, the NKPC is negatively affected by real money balances. Note that when $\chi = 0$, the NKPC reduces to one derived in the standard NK model.

The third equation is a money demand function derived from the household's optimization problem for money holdings (Walsh, 2017, Woodford, 2003). More specifically, it is derived from the fact that the marginal rate of substitution between consumption and real money balances equals the opportunity costs of money holdings. The money demand function is given by

$$m_t = \eta_y x_t - \eta_r r_t, \tag{4}$$

where η_y denotes the income elasticity of money demand, and η_r represents the interest elasticity of money demand. The money demand function does not rely on the assumption of the nonseparable utility between consumption and real money balances (Woodford, 2003).

We conduct a further analytical investigation, providing the following two-equation system by substituting Equation (4) into Equations (1) and (2) as follows:

$$x_t = E_t x_{t+1} - \frac{1}{\tilde{\sigma}}(r_t - E_t \pi_{t+1}) + \frac{\chi \eta_r}{\tilde{\sigma}} E_t \Delta r_{t+1}, \tag{5}$$

$$\pi_t = \beta E_t \pi_{t+1} + \tilde{\lambda} x_t + \lambda \chi \eta_r r_t, \tag{6}$$

where $\tilde{\sigma} = \sigma - \chi \eta_y$ and $\tilde{\lambda} = \lambda(\sigma + \varphi - \chi \eta_y)$. According to Equation (6), the inflation rate positively depends on the nominal interest rate due to the presence of the RMBE, provided $\chi > 0$.[8] Following Kurozumi (2006) and Woodford (2003), we assume that $\sigma - \chi \eta_y > 0$ to avoid the inverted IS logic. Under an empirically plausible parameterization, we can confirm that the assumption is satisfied.

In what follows, we explain how the RMBE operates in this model. Consider the case for a nominal interest rate increase, which reduces the output gap via the following two channels. First, raising the nominal interest rate reduces real money balances. According to Equation (1), the output gap decreases if the first difference in real balances decreases, reflecting the

[8] As Ravenna and Walsh (2006) showed, the NKPC positively depends on the nominal interest rate in an NK model with a cost channel because the real marginal costs increase along with the nominal interest rate. See Ravenna and Walsh (2006) for a detailed discussion about the cost channel in the NK model. We will discuss the difference between the cost channel and the RMBE.

RMBE. Second, a rise in the nominal interest rate directly reduces the output gap via the interest rate's traditional demand channel. Due to the above two channels, a decrease in the output gap results in a decline in inflation.

Conversely, the inflation rate increases because the real marginal costs depend on the nominal interest rate in an NK model with real money balances. The third term of the right-hand side in the NKPC captures this effect. According to this NKPC, the real marginal costs negatively depend on the real money balances. The intuition of this term is as follows (Dorich, 2009). An increase in the nominal interest rate lowers the demand for money, which induces a decline in the marginal utility of consumption, increasing the real wage via the marginal rate of substitution between consumption and labor supply. An increase in the real wage creates a further real marginal cost, resulting in inflation. These arguments imply that a persistent inflation target shock may generate the NFE when the supply channel of the nominal interest rate outweighs the demand channel.

We briefly comment on the difference between the cost channel and the RMBE. Ali and Qureshi (2022) documented the role of the cost channel when accounting for the NFE. As noted, the cost channel indicates that an increase in the nominal interest rate leads to inflation via a rise in the firm's working capital. In contrast, we focus on how the occurrence of the NFE is affected by the RMBE. Unlike the cost channel, the RMBE documents the role of the money aggregate. In particular, whether the RMBE induces inflation relies on the degree of the nonseparability parameter between consumption and real money balances. As noted, several studies empirically reported the RMBE measured by this parameter (Benchimol and Fourçans, 2012, Dorich, 2009, Favara and Giordani, 2009, Poilly, 2010, Serletis and Xu, 2020). To our knowledge, no extant research has attempted to answer this question.

We now describe the monetary policy specification. We do not assume a simple monetary policy rule, such as the Taylor rule (Taylor, 1993); instead, we follow Garín et al. (2018) and presume that an exogenous inflation target specifies monetary policy.[9] An auto-regressive (AR)(1) process characterizes an exogenous inflation target shock. The central bank manipulates the nominal interest rate to achieve its inflation target. In the following, we assume the

[9] Ali and Qureshi (2022) adopted a simple Taylor rule to investigate the occurrence of the NFE in an NK model.

following monetary policy specification:

$$\pi_t = \pi_t^*, \tag{7}$$

$$\pi_t^* = \rho_\pi \pi_{t-1}^* + \varepsilon_t, \tag{8}$$

where $\rho_\pi \in [0, 1)$ denotes the degree of inflation target shock persistence. ε_t is an independent and identically distributed shock with the constant variable σ_π^2.

As stated, how the RMBE influences the NFE is unclear; thus, we must investigate whether an inflation target shock causes a rise in the nominal interest rate. Consider the case of an exogenous inflation target shock. On the one hand, this shock immediately increases inflation. Given the nominal money aggregate, it leads to a decline in real money balances. Conversely, the money demand function implies that a decrease in real money balances raises the nominal interest rate. Therefore, unlike Garín et al. (2018), the NFE may be amplified or dampened by the RMBE. The following section explores how the separability parameter χ affects generating the NFE.

2.2 Parameterization

This study's deep parameters are based on those in the standard NK analyses. More precisely, following Garín et al. (2018), we set the discount factor β, the relative risk aversion coefficient for consumption σ, and the inverse elasticity of the labor supply φ, as 0.99, 1.0, and 1.0, respectively. We set the interest elasticity of money demand η_r to 16.0, and the value of the income elasticity of money demand η_y is 1.0.[10]

Next, consider the calibration of the degree of the nonseparability parameter between consumption and real money balances, χ. To be consistent with the empirical value of the nonseparability parameter, we focus on the assumption of $\chi \geq 0$. No consensus appears to have been reached among previous empirical studies regarding the estimated value of parameter χ. In an earlier study, a nonseparable utility function resulted in poorer empirical performance (Ireland, 2001). Conversely, several recent studies reported a statistically significant nonseparable parameter χ (Dorich, 2009, Favara and Giordani, 2009, Poilly, 2010, Serletis and Xu, 2020). Woodford (2003) considered the smaller value of χ; however, several studies reported a

[10]A larger value of η_r may lead to unstable inflation dynamics when we allow a larger value of the nonseparability parameter. A detailed discussion regarding this issue is available from the author.

larger value of this parameter (Dorich, 2009, Jia, 2021, Piazzesi, Rogers and Schneider, 2019), ranging from 0.05 to 1.5. Ida (2023) considered that the value of χ ranged from 0 to 0.05. While our study may calibrate a larger value of χ, unfortunately, Kurozumi (2006) showed that the rational expectations (RE) equilibrium will likely be indeterminate if this value is above 0.02. McKnight and Mihailov (2015) supported this finding.[11] Despite the disagreement over the precise ranges of this parameter, we set parameter χ to a range of 0 to 0.1 to obtain the stable equilibrium response of inflation. We confirm that the equilibrium response is stable under this parameter range; we do not assert that the RMBE is negligible even if this parameter takes a low value.

3 Main results

This section reports this study's main findings. Section 3.1 investigates the response of the nominal interest rate to an inflation target shock and confirms the condition of the emerging NFE. Section 3.2 reports the sensitivity experiments with various parameterizations.

3.1 The NFE in an NK model with real money balances

Consider how the nominal interest rate reacts to an inflation target shock. We solve the RE model by considering the undetermined coefficient method (UCM), allowing us to derive an analytical solution using several intuitions about why the NFE occurs in this paper. McCallum (1983) proposed the minimum state variable (MSV) solution to obtain the analytical solution in the RE model; we follow their approach to seek the MSV solution using the UCM.[12] Accordingly, we can derive the MSV solution for the interest rate as follows:

$$r_t = \Psi \pi_t^*, \tag{9}$$

where

$$\Psi = \frac{\tilde{\sigma}(1-\rho_\pi \beta)(\rho_\pi - 1) + \tilde{\lambda}\rho_\pi}{\Omega},$$
$$\Omega = \lambda\{(\sigma + \varphi - \chi\eta_y)[1 - \chi\eta_r(\rho_\pi - 1)] - \tilde{\sigma}\chi\eta_r\}.$$

[11] They assumed that the nonseparability parameter ranges from 0 to 0.03.

[12] Concentrating on the MSV solution excludes the bubble solution in the RE model.

Without loss of generality, the following analyses assume $\Omega > 0$. Similarly, for the output gap, we obtain the MSV solution as follows:

$$x_t = \Gamma \pi_t^*, \tag{10}$$

where

$$\Gamma = \frac{(1 - \rho_\pi \beta)[\Omega - \chi \eta_r \lambda \tilde{\lambda} \tilde{\sigma}(\rho_\pi - 1)] - \tilde{\lambda}^2 \rho_\pi}{\Omega \tilde{\lambda}}.$$

Finally, the real interest rate (rr_t) is given as follows:

$$\begin{aligned} rr_t &= r_t - E_t \pi_{t+1}, \\ &= (\Psi - \rho_\pi) \pi_t^*. \end{aligned} \tag{11}$$

Consider how a change in parameter χ impacts the response of the nominal interest rate to an inflation target shock. As Garín et al. (2018) pointed out, the numerator in the coefficient Ψ is likely to be positive in this model. In contrast to Garín et al. (2018), we consider that parameter χ significantly affects the response of the nominal interest rate to an inflation target shock. A higher value of χ lowers the denominator in Ψ; however, it also decreases the numerator in its coefficient. Accordingly, we conjecture that a higher value of χ reinforces an inflation target shock's positive effect on the nominal interest rate if the former effect outweighs the latter. Therefore, it follows from Equation (11) that this situation naturally influences the response of the real interest rate to an inflation target shock. When the separable utility between consumption and real money balances is assumed (i.e., $\chi = 0$), the solution (9) reduces to that derived by Garín et al. (2018).

First, we investigate whether increasing the parameter χ reinforces or dampens an inflation target shock's effect on the nominal interest rate. In other words, we investigate whether a change in parameter χ affects the sensitivity of the nominal interest rate response to an inflation target shock. We have the following result:

Proposition 1 *Let $\rho_\pi > \theta$ and $\chi \geq 0$. An increase in the parameter χ always reinforces the positive effect of an inflation target shock on the nominal interest rate if $(1 - \rho_\pi \beta)(1 - \rho_\pi) > \lambda \rho_\pi$ and $\eta_y \{\chi \eta_r [\lambda \eta_y (\rho_\pi - 1) + 1] - \lambda\} < \eta_r \{\tilde{\sigma} + \lambda(\rho_\pi - 1)(\sigma + \tilde{\sigma} + \varphi)\}$.*

Proof. Differentiating the coefficient Ψ with respect to χ, we obtain the following result:

$$\frac{\partial \Psi}{\partial \chi} = \frac{AB - CD}{B^2},$$

where

$$A = \eta_y[(1 - \rho_\pi \beta)(1 - \rho_\pi) - \lambda \rho_\pi],$$

$$B = \tilde{\lambda}(1 - \chi \eta_r(\rho_\pi - 1)) - \chi \eta_r \tilde{\sigma} > 0,$$

$$C = \tilde{\sigma}(1 - \rho_\pi \beta)(1 - \rho_\pi) + \tilde{\lambda} > 0,$$

$$D = \eta_y\{\chi \eta_r[\lambda \eta_y(\rho_\pi - 1) + 1] - \lambda\} - \eta_r\{\tilde{\sigma} + \lambda(\rho_\pi - 1)(\sigma + \tilde{\sigma} + \varphi)\}.$$

Since the denominator is positive, this derivative always becomes positive if A is positive and D is negative. When $\rho_\pi > \theta$, the coefficient A becomes positive. Furthermore, we require the following condition for the coefficient D to be negative: $\eta_y\{\chi \eta_r[\lambda \eta_y(\rho_\pi - 1) + 1] - \lambda\} < \eta_r\{\tilde{\sigma} + \lambda(\rho_\pi - 1)(\sigma + \tilde{\sigma} + \varphi)\}$. We obtain $\partial \Psi / \partial \chi > 0$ if these conditions are satisfied. This completes the proof. ■

The intuition of this result is as follows. Consider the case of an exogenous inflation-targeting shock, which immediately causes an increase in inflation. Given the nominal money aggregate, a rise in the inflation rate generates a decline in real money balances, increasing the nominal interest rate. Given the degree of nominal price stickiness, a higher value of ρ_π indicates a more substantial effect of an inflation target shock on the actual inflation rate. Therefore, for the case of a higher value of ρ_π, the RMBE is likely to create a larger NFE.

Based on the calibrated values reported in Section 2.2, we numerically check how the degree of nonseparability χ influences an inflation target shock's impact on the nominal interest rate. Figure 1 shows the response of the nominal interest rate to an inflation target shock when ρ_π exceeds 0.5. An increased value of χ reinforces the positive impact of an inflation target shock on the nominal interest rate; therefore, unlike Garín et al. (2018), we demonstrate the impact of the RMBE on the NFE in an NK model. For even a smaller value of χ, the RMBE plays a significant role in explaining the NFE.

[Figure 1 around here]

The above result raises the question: How does the RMBE affect the occurrence of the NFE? The NFE requires $\partial r_t / \partial \pi_t^* > 0$; however, how does a change in χ help generate this effect? We provide the following proposition to consider the role of the parameter χ:

Proposition 2 *Let $\rho_\pi \neq \theta$. In an NK model with real money balances, the NFE emerges if either $\chi > \chi^*$ when $\rho_\pi < \theta$ or if $\chi < \chi^*$ when $\rho_\pi > \theta$.*

Proof. The NFE requires that $\partial r_t/\partial \pi_t^* > 0$, implying $\Psi > 0$ in Equation (9). Here, the threshold of χ that determines whether the NFE occurs is given as follows:

$$\chi^* = \frac{\sigma(1-\rho_\pi\beta)(\rho_\pi - 1) + \lambda(\sigma+\varphi)\rho_\pi}{\eta_y[(1-\rho_\pi\beta)(\rho_\pi - 1) + \rho_\pi\lambda]}. \tag{12}$$

We obtain the condition $-(1-\rho_\pi)(1-\rho_\pi\beta)+\rho_\pi\lambda < 0$ in the case of $\rho_\pi > \theta$. In this case, a value of χ that is less than this threshold (i.e., $\chi < \chi^*$) produces $\Psi > 0$. This situation indicates that the value of χ that is smaller than the threshold χ^* generates the NFE; however, the opposite case occurs when $\theta > \rho_\pi$. More precisely, the value of χ that exceeds this threshold (i.e., $\chi > \chi^*$) leads to the condition $\Psi > 0$ in this case. This outcome occurs because the threshold takes a smaller value as ρ_π increases in the case of $\theta > \rho_\pi$; therefore, the value of χ that exceeds the threshold χ^* creates the NFE. This completes the proof. ■

This proposition states that the value of ρ_π relative to θ becomes significant in determining the threshold of χ in an NK model with real money balances. This result's intuition is as follows. A positive inflation target shock implies that the inflation rate will rise; a larger value of ρ_π amplifies this effect. Conversely, a higher value of the parameter θ dampens the response of the inflation rate to the economic shock. Furthermore, in the case of $\chi > 0$, the nominal interest rate positively affects the inflation rate via the RMBE in the NKPC. Accordingly, in the case of $\rho_\pi > \theta$, an inflation target shock increases inflation via the RMBE because the former effect dominates the latter one; thus, the strong RMBE captured by a larger value of χ easily amplifies the NFE. As long as the condition $\rho_\pi > \theta$ is satisfied, a lower value of χ can produce the positive response of the nominal interest rate to a persistent inflation target shock. When $\theta > \rho_\pi$, a higher value of the parameter χ is required to generate the NFE via the RMBE in the NKPC because an inflation target shock may have difficulty in inducing a persistent increase in inflation.

Based on the calibrated values in Section 2.2, the following discussion numerically examines the threshold of χ to cause the NFE. Figure 2 illustrates the thresholds of χ when $\theta = 0.7$. This chart shows that when $\rho_\pi > \theta$, a much smaller value of χ satisfies the neo-Fisherian region, and an inflation target shock leads to a rise in the nominal interest rate. For the larger value of ρ_π, we can easily find the empirically plausible value of χ that satisfies the condition of Proposition 2. Conversely, a larger value of χ that exceeds the threshold of χ does not generate the NFE when ρ_π is larger. Furthermore, the value of χ that exceeds the threshold χ^* generates the

NFE as long as $\theta > \rho_\pi$. Finally, this figure shows that despite the degree of the nonseparable parameter, the NFE may occur when the parameter ρ_π ranges from 0.61 to 0.75.[13]

As noted, previous empirical studies do not support such a sufficiently large value of χ. Furthermore, Kurozumi (2006) and McKnight and Mihailov (2015) showed that such a larger value easily makes the RE equilibrium indeterminate in our model. Therefore, the following exercises exclude a larger nonseparability parameter value. Summing up, the calibration of $\theta = 0.7$ is standard in the NK model (Walsh, 2017, Woodford, 2003). Moreover, as Section 2.2 showed, previous studies support a range of χ between 0 and 0.1; thus, under empirically plausible calibrated values, we successfully obtain the positive response of the interest rate to an inflation target shock.

[Figure 2 around here]

Figure 3 shows the nominal interest rate's impact response to an inflation target shock under several parameterizations of χ when θ is fixed at 0.7. First, consider the case of no RMBE, i.e., $\chi = 0$, which corresponds to the case of Garín et al. (2018). When the parameter ρ_π is below 0.6, an inflation target shock reduces the nominal interest rate, consistent with Garín et al. (2018). Second, consider the case with the RMBE. Regardless of the nonseparability parameter degree, no positive relationship exists between inflation and the nominal interest rate if the parameter ρ_π is less than 0.6. Thus, despite the degree of the nonseparability parameter, an inflation target shock always leads to a negative response of the nominal interest rate, provided $\theta > \rho_\pi$. As in Garín et al. (2018), the NFE occurs when the parameter ρ_π exceeds 0.6. Particularly, we address that a larger value of χ amplifies the NFE when introducing a persistent but transitory inflation target shock.

[Figure 3 around here]

Figure 4 shows the impulse response of the nominal interest rate to an inflation target shock in the case of $\rho_\pi = 0.65$. Garín et al. (2018) showed that the impact response of the nominal interest rate to the shock is positive when ρ_π is above 0.6, which the result of our model

[13] Thus, this figure implies that the NFE occurs when the parameter χ takes a larger value above 1.5 reported by Dorich (2009); however, such a parameter value will likely cause a severe indeterminacy problem in this model (Kurozumi, 2006).

confirms in the case of $\chi = 0$. We stress that a higher value of χ creates a larger response of the nominal interest rate to an inflation target shock. Intuitively, given the degree of nominal price stickiness, a higher value of χ strengthens the RMBE, increasing the inflation rate via the NKPC; thus, a persistent inflation target shock further raises the nominal interest rate under the RMBE, reinforced by a higher nonseparability parameter value.

[Figure 4 around here]

3.2 Sensitivity experiments

This section presents sensitivity experiments. First, we consider whether the degree of nominal price stickiness significantly affects the impact of real money balances on the NFE. Garín et al. (2018) showed that the degree of nominal price stickiness is critical for the occurrence of the NFE; when nominal price stickiness is high enough, the effect does not appear unless a highly persistent inflation target shock is introduced. Given the values of θ and ρ_π, we consider whether the degree of χ affects the occurrence of the NFE in our study.

Figure 5 shows how changing the parameter χ affects the nominal interest rate's response to an inflation target shock under several parameterizations of nominal price stickiness θ. First, consider the case for flexible nominal prices. Consistent with Garín et al. (2018), a persistent inflation target shock increases the nominal interest rate. More concretely, given a value of χ, a higher value of ρ_π amplifies an inflation target shock's impact on the nominal interest rate.

[Figure 5 around here]

We next examine how the degree of nominal price stickiness affects NFE occurrences in an NK model with real money balances. With moderate nominal price stickiness, as in Garín et al. (2018), an inflation target shock decreases the nominal interest rate when it is less persistent. The right-upper panel in Figure 5 shows that the nominal interest rate is negatively related to an inflation target shock when ρ_π is less than 0.4. Similar to flexible nominal prices, a higher value of χ amplifies the impact response of the nominal interest rate when an inflation target shock is predominantly persistent. When the calibrated value of θ is assumed as the benchmark case (i.e., $\theta = 0.7$), the NFE disappears provided ρ_π is less than 0.6. Unlike Garín et al. (2018), a higher value of χ dampens the negative impact of an inflation target shock on the nominal interest rate. In the case of $\theta = 0.7$, the NFE emerges when ρ_π exceeds 0.6. An increased parameter χ still significantly affects the impact on the response of the nominal interest rate.

Figure 5 (iv) illustrates the impact of an inflation target shock on the nominal interest rate due to an inflation target shock when nominal price stickiness is exceptionally high. Garín et al. (2018) shows that the NFE does not occur as long as an inflation target shock is predominantly persistent. As in the case of $\theta = 0.7$, a higher value of χ dampens an inflation target shock's negative impact on the nominal interest rate for a smaller value of ρ_π. Interestingly, when nominal prices are highly sticky, the impact on the nominal interest rate is almost unaffected by an increased parameter χ even if ρ_π takes a considerably high value.

Next, we present the impulse response of several key macrovariables to an inflation target shock. Figures 6 (i) and (ii) depict the impulse response when the inflation target shock is not persistent. A positive inflation target shock raises the inflation rate while lowering the nominal interest rate. A fall in the nominal interest rate increases the output gap but decreases the real interest rate. If an inflation target shock is less persistent, the impulse responses are unaffected by a change in the parameter χ.

Figure 6 (iii) shows that in the case of $\rho_\pi = 0.6$, the real interest rate response is unaffected by a change in χ. The response of the nominal interest rate becomes negative where χ is less than 0.02; however, the case of $\chi = 0.05$ produces a smaller negative response of the nominal interest rate to an inflation target shock. In contrast, for $\chi = 0.1$, the inflation target shock increases the nominal interest rate when it has moderate persistence.

Finally, consider the case of $\rho_\pi = 0.9$. Figure 6 (iv) illustrates that the response of the nominal interest rate significantly becomes positive after an inflation target shock, namely, the occurrence of the NFE. A higher value of the nonseparability parameter amplifies the NFE, while a reduction in the real interest rate is also attenuated since a higher value of χ causes a further increase in the nominal interest rate. In particular, for $\chi = 0.05$ and $\chi = 0.1$, the real interest rate significantly increases when $\rho_\pi = 0.9$, further reducing the output gap through an IS curve. More precisely, a drop in the output gap is the largest in the case of $\chi = 0.05$; however, it increases after the shock in the case of $\chi = 0.1$.

[Figure 6 around here]

4 Endogenous inflation persistence: Revisit

This section designs a further robustness check, introducing endogenous inflation persistence into the model. Garín et al. (2018) showed that the presence of lagged inflation stemming from inflation persistence eliminates the occurrence of the NFE in a standard NK model. Several studies argued the importance of endogenous inflation persistence in monetary policy analyses (Amato and Laubach, 2003, Galí and Gertler, 1999, Ida, 2020). We check whether incorporating inflation persistence into the model prevents the occurrence of the NFE in an NK model with the RMBE.

We employ a rule-of-thumb hypothesis, following Galí and Gertler (1999) and Amato and Laubach (2003).[14] Among firms that optimally set their prices, a fraction $(0 \leq \omega \leq 1)$ sets prices based on a rule-of-thumb. The remaining fraction of firms $(1-\omega)$ set their prices according to the standard Calvo pricing model. This modification creates the lagged inflation in the NKPC; thus, under a rule-of-thumb hypothesis, the hybrid NKPC is given as follows:

$$\pi_t = \gamma_f E_t \pi_{t+1} + \gamma_b \pi_{t-1} + \tilde{\zeta} x_t, \tag{13}$$

where

$$\gamma_f = \frac{\theta\beta}{\theta + \omega[1-\theta(1-\beta)]};\ \gamma_b = \frac{\omega}{\theta + \omega[1-\theta(1-\beta)]};\ \zeta = \frac{(1-\omega)(1-\theta)(1-\theta\beta)}{\theta + \omega[1-\theta(1-\beta)]},$$

and $\tilde{\zeta} = \zeta(\sigma + \varphi - \chi\eta_y)$. It immediately turns out that a larger value of ω causes a greater impact of the lagged inflation rate on inflation dynamics. When $\omega = 0$, we obtain the purely forward-looking NKPC.

Following Garín et al. (2018), we can derive the interest rate path under the hybrid NKPC as follows:

$$i_t = \left[1 - \frac{\chi\eta_r(\tilde{\sigma}^{-1}\tilde{\zeta} - \zeta)}{q} L^{-1}\right]^{-1} \left\{ \left[\frac{(1-\rho_\pi)(\rho_\pi - 1) - \gamma_b + \tilde{\sigma}^{-1}\tilde{\zeta}\rho_\pi}{q}\right]\pi_t^* + \frac{\gamma_b}{q}\pi_{t-1}^* \right\}, \tag{14}$$

where L denotes the lag operator and $q = \tilde{\sigma}^{-1}\tilde{\zeta}(1+\chi\eta_r) - \zeta\chi\eta_r$. This is a slightly messy expression; thus, this interest rate path may not correspond to the MSV solution because it contains the term for the expected nominal interest rate characterized by the lag operator.

[14] Alternatively, we can obtain the NKPC with lagged inflation by assuming the indexation rule. See Woodford (2003) for a detailed discussion.

Nonetheless, we can infer that the impact of this term on current interest rates is not substantial under our benchmark calibration. We have some merits from this benchmark expression because Equation (14) is directly comparable with that derived in Garín et al. (2018). For instance, we can easily check the interest rate path (14) that corresponds to Garín et al. (2018) when $\chi = 0$.

Like Garín et al. (2018), we focus on this equation's coefficient π_t^*. Following Garín et al. (2018), we numerically check this issue because we cannot analytically derive how the inclusion of the lagged inflation rate affects the NFE in our study. Figure 7 illustrates the coefficient on π_t^* as a function of ρ_π, ω, and χ. As shown earlier, a persistent inflation target shock increases the nominal interest rate in the purely forward-looking Phillips curve, namely, $\omega = 0$; however, like Garín et al. (2018), introducing endogenous inflation persistence prevents the occurrence of the NFE in our study. This figure shows that a larger value of ω causes a further reduction of the nominal interest rate after the inflation target shock. Even in this case, a larger value of χ eases a decline in the nominal interest rate. We conjecture that an adequately high value of χ that exceeds 0.1 may lead to a positive response of the nominal interest rate after this shock. As noted, we cannot employ such a larger value of χ, which easily generates the unstable solution. In summary, while the RMBE amplifies the NFE in a purely forward-looking NK model, lagged inflation excludes this channel. Except for the nonseparability parameter, this result is consistent with Garín et al. (2018).

[Figure 7 around here]

5 Discussion

This section presents the policy implications of our findings. This study investigated whether the RMBE accounts for the occurrence of the NFE in an NK model. The presence of the RMBE may not fully explain the occurrence of the NFE; however, we found that increasing the nonseparability parameter strengthens the effect of the RMBE on the NFE. This finding implies that the money demand function significantly impacts the NFE as long as the central bank does not face nonnegativity constraints on nominal interest rates.[15] As Garín et al. (2018) showed, a

[15]This is because once the nominal interest rate reaches the effective lower-bound floor, the money demand function may no longer hold.

persistent inflation target shock generates a positive response of the nominal interest rate to an inflation target shock, given the standard calibrated value of nominal price stickiness. Unlike Garín et al. (2018), we demonstrated that a higher value of the nonseparability parameter magnifies the NFE via the RMBE.

Our finding has several implications for monetary policy. Due to a negative shock's deflationary risk to the natural interest rate, central banks in advanced countries have set their nominal interest rates at an effective lower-bound floor; however, since 2022, such banks have sought to raise nominal interest rates to combat an inflationary risk where actual inflation exceeds the central bank's inflation target. According to the neo-Fisherian hypothesis, a higher inflation target value increases the nominal interest rate. Furthermore, as Woodford (2003) showed, in an economy with the RMBE, an NKPC indicates that a decrease in real money balances raises the inflation rate through a rise in the nominal interest rate. This channel becomes the source of the amplification mechanism of the NFE, which theoretical and empirical studies have addressed.

The zero lower bound on nominal interest rates breaks the stable money demand relationship between money and the interest rate (Ida, 2023); however, such a relationship is revived when interest rates are positive. If nominal prices are not too sticky, the RMBE significantly strengthens the NFE when we permit a persistent inflation target shock.[16] As a result, this study considers that central banks should consider the role of the RMBE when analyzing the relationship between its target inflation rate and the nominal interest rate. This approach can help combat inflationary pressures on the economy. Williamson (2019) stated the importance of money aggregate in the Volker era, arguing that movements in inflation and nominal interest rates were consistent with the concept of neo-Fisherianism. Recent studies have also argued for a role of monetary aggregate (Belongia and Ireland, 2018, Billi, Söderström and Walsh, 2020, Jia, 2021); therefore, our study has important policy implications for recent monetary policy analysis.

[16] We do not consider the role of the RMBE in accounting for the NFE when a liquidity trap occurs. See Bilbiie (2022) for a detailed discussion of the NFE under a liquidity trap.

6 Conclusions

Does a rise in the central bank's target inflation induce a rise in the nominal interest rate? This simple question has recently become critical to the effectiveness of monetary policy in advanced economies. According to standard macroeconomics, we would expect that the inflation rate generally declines after a rise in the nominal interest rate. Conversely, the neo-Fisherian hypothesis indicates the positive comovement between the nominal interest rate and inflation in the short run. Recently, several studies focused on the real money balance channel, implying that a change in money balances impacts the aggregate demand via monetary policy's demand and supply channels.

Our study focuses on the role of the nonseparability parameter, capturing the RMBE, in considering the occurrence of the NFE. The main findings of this paper are summarized as follows. First, the presence of the RMBE can partly explain the occurrence of the NFE. In particular, this study addresses the fact that increasing the nonseparability parameter magnifies the positive response of the nominal interest rate to a persistent inflation target shock. Second, the degree of nominal price stickiness is important in explaining how the RMBE amplifies the NFE. Third, introducing inflation inertia into the Phillips curve eliminates the NFE even if we allow the strong RMBE in the model.

Although this study focused on the case of an inflation target shock as a monetary policy specification, other monetary policy rules, such as the Taylor rule, could also be considered. It would be interesting to see if the RMBE significantly impacts the NFE under an alternative monetary policy rule. Furthermore, our model is based on the purely forward-looking NK model with real money balances; however, we introduced the lagged inflation rate in the NKPC under the assumption of the rule-of-thumb hypothesis. We assume the DIS curve is still purely forward-looking to obtain the analytical solution; therefore, we intend to extend it with lagged endogenous variables in the DIS curve via consumption habit formation. Regarding this point, we can consider the impact of the nonseparability parameter on the NFE in the medium-size dynamic stochastic general equilibrium model.

References

Airaudo, M., Hajdini, I., 2023. Wealth effects, price markups, and the neo-fisherian hypothesis. European Economic Review , 104482.

Ali, S.Z., Qureshi, I.A., 2022. A note on the Neo-Fisher effect in the New Keynesian model. Macroeconomic Dynamics , 1–17.

Amato, J.D., Laubach, T., 2003. Rule-of-thumb behaviour and monetary policy. European Economic Review 47, 791–831.

Belongia, M., Ireland, P., 2018. Targeting constant money growth at the zero lower bound. International Journal of Central Banking 14, 159–204.

Belongia, M.T., Ireland, P.N., 2022. A reconsideration of money growth rules. Journal of Economic Dynamics and Control , 104312.

Benchimol, J., Fourçans, A., 2012. Money and risk in a dsge framework: a bayesian application to the eurozone. Journal of Macroeconomics 34, 95–111.

Benhabib, J., Schmitt-Grohé, S., Uribe, M., 2001. Monetary policy and multiple equilibria. American Economic Review 91, 167–186.

Bilbiie, F.O., 2022. Neo-fisherian policies and liquidity traps. American Economic Journal: Macroeconomics 14, 378–403.

Billi, R.M., Söderström, U., Walsh, C.E., 2020. The role of money in monetary policy at the lower bound .

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

Cochrane, J.H., 2016. Do higher interest rates raise or lower inflation? Unpublished paper, February, https://faculty. chicagobooth. edu/john. cochrane/research/papers/fisher. pdf .

Dorich, J., 2009. Resurrecting the role of real money balance effects. Technical Report. Bank of Canada Working Paper.

Favara, G., Giordani, P., 2009. Reconsidering the role of money for output, prices and interest rates. Journal of Monetary Economics 56, 419–430.

Florio, A., 2018. Nominal anchors and the price puzzle. Journal of Macroeconomics 58, 224–237.

Galí, J., Gertler, M., 1999. Inflation dynamics: A structural econometric analysis. Journal of Monetary Economics 44, 195–222.

Garín, J., Lester, R., Sims, E., 2018. Raise rates to raise inflation? Neo-Fisherianism in the New Keynesian model. Journal of Money, Credit and Banking 50, 243–259.

Hanson, M.S., 2004. The "price puzzle" reconsidered. Journal of Monetary Economics 51, 1385–1413.

Ida, D., 2020. Sectoral inflation persistence and optimal monetary policy. Journal of Macroeconomics 65, 103215.

Ida, D., 2023. The effect of real money balances on international monetary policy transmission. Journal of International Money and Finance 139, 102964.

Ida, D., 2024. Household heterogeneity and the price puzzle in a new Keynesian model. Journal of Macroeconomics 79, 103587.

Ireland, P.N., 2001. Money's role in the monetary business cycle.

Jia, P., 2021. Understanding a New Keynesian model with liquidity .

Kurozumi, T., 2006. Determinacy and expectational stability of equilibrium in a monetary sticky-price model with Taylor rule. Journal of Monetary Economics 53, 827–846.

McCallum, B.T., 1983. On non-uniqueness in rational expectations models: An attempt at perspective. Journal of Monetary Economics 11, 139–168.

McKnight, S., Mihailov, A., 2015. Do real balance effects invalidate the Taylor principle in closed and open economies? Economica 82, 938–975.

Piazzesi, M., Rogers, C., Schneider, M., 2019. Money and banking in a New Keynesian model. Standford WP .

Pigou, A.C., 1943. The classical stationary state. The Economic Journal 53, 343–351.

Poilly, C., 2010. Does money matter for the identification of monetary policy shocks: A DSGE perspective. Journal of Economic Dynamics and Control 34, 2159–2178.

Ravenna, F., Walsh, C.E., 2006. Optimal monetary policy with the cost channel. Journal of Monetary Economics 53, 199–216.

Serletis, A., Xu, L., 2020. Functional monetary aggregates, monetary policy, and business cycles. Journal of Economic Dynamics and Control 121, 103994.

Sims, C.A., 1992. Interpreting the macroeconomic time series facts: The effects of monetary policy. European Economic Review 36, 975–1000.

Taylor, J.B., 1993. Discretion versus policy rules in practice, in: Carnegie-Rochester conference series on public policy, Elsevier. pp. 195–214.

Uribe, M., 2022. The neo-Fisher effect: Econometric evidence from empirical and optimizing models. American Economic Journal: Macroeconomics 14, 133–62.

Walsh, C.E., 2017. Monetary Theory and Policy. MIT press.

Williamson, S., 2019. Neo-fisherism and inflation control. Canadian Journal of Economics 52, 882–913.

Woodford, M., 2003. Interest and Prices: Foundations of a Theory of Monetary Policy. Princeton university press.

Figure 1: The effect of χ on the coefficient Ψ

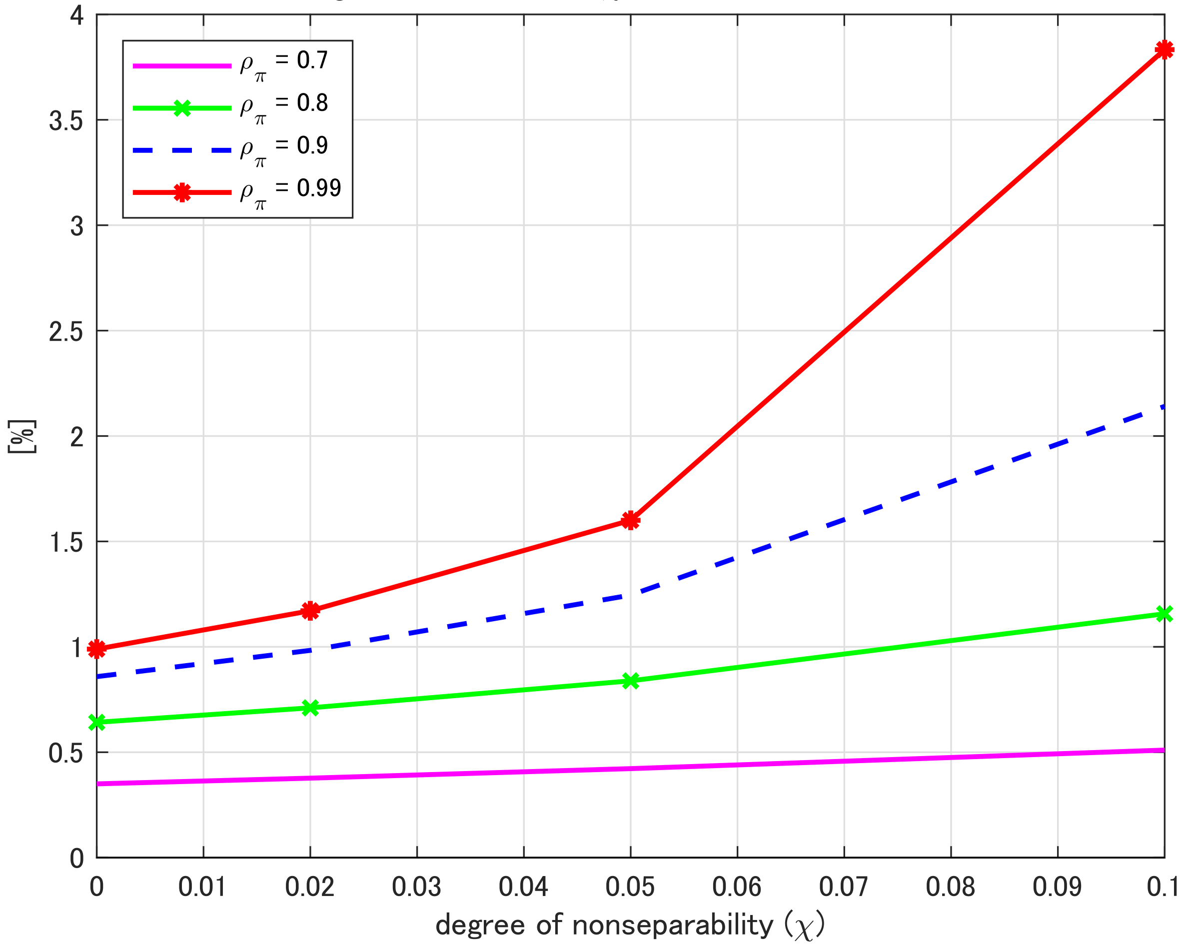


Figure 2: Threshold of χ and the NFE

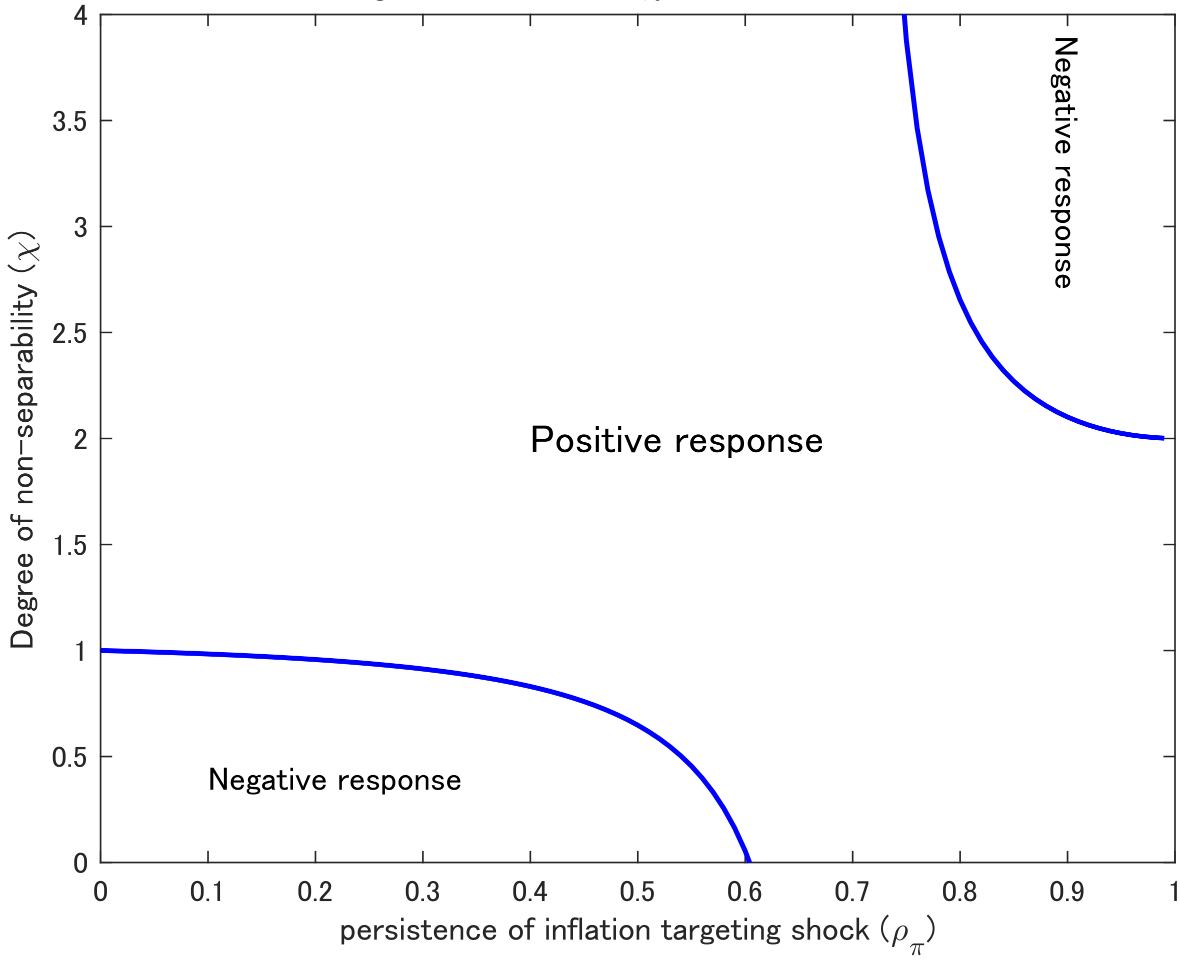


Figure 3: Impact response of the nominal interest rate to an inflation-targeting shock: The role of χ

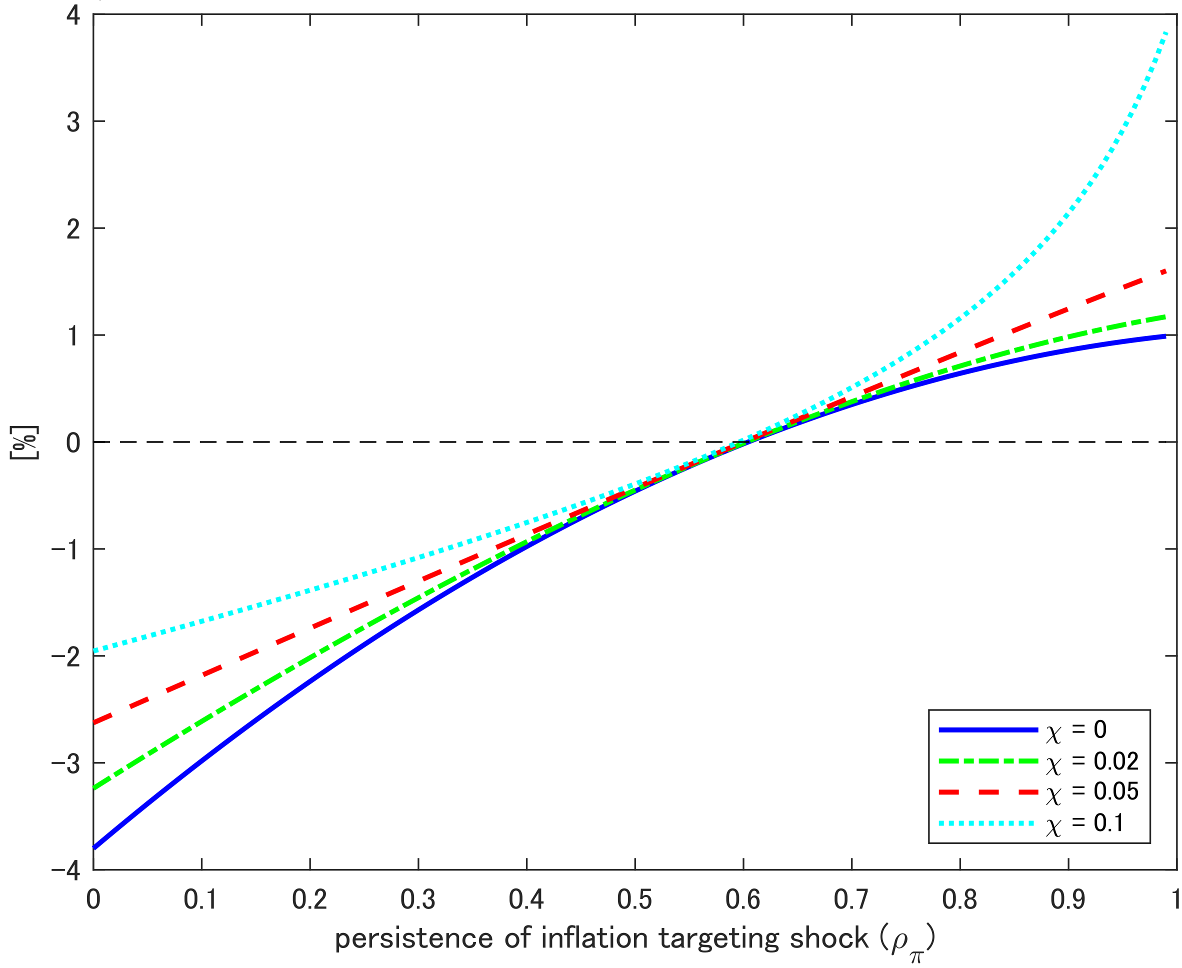


Figure 4: Impulse response of the nominal interest rate to an inflation-targeting shock: $\rho_\pi = 0.65$

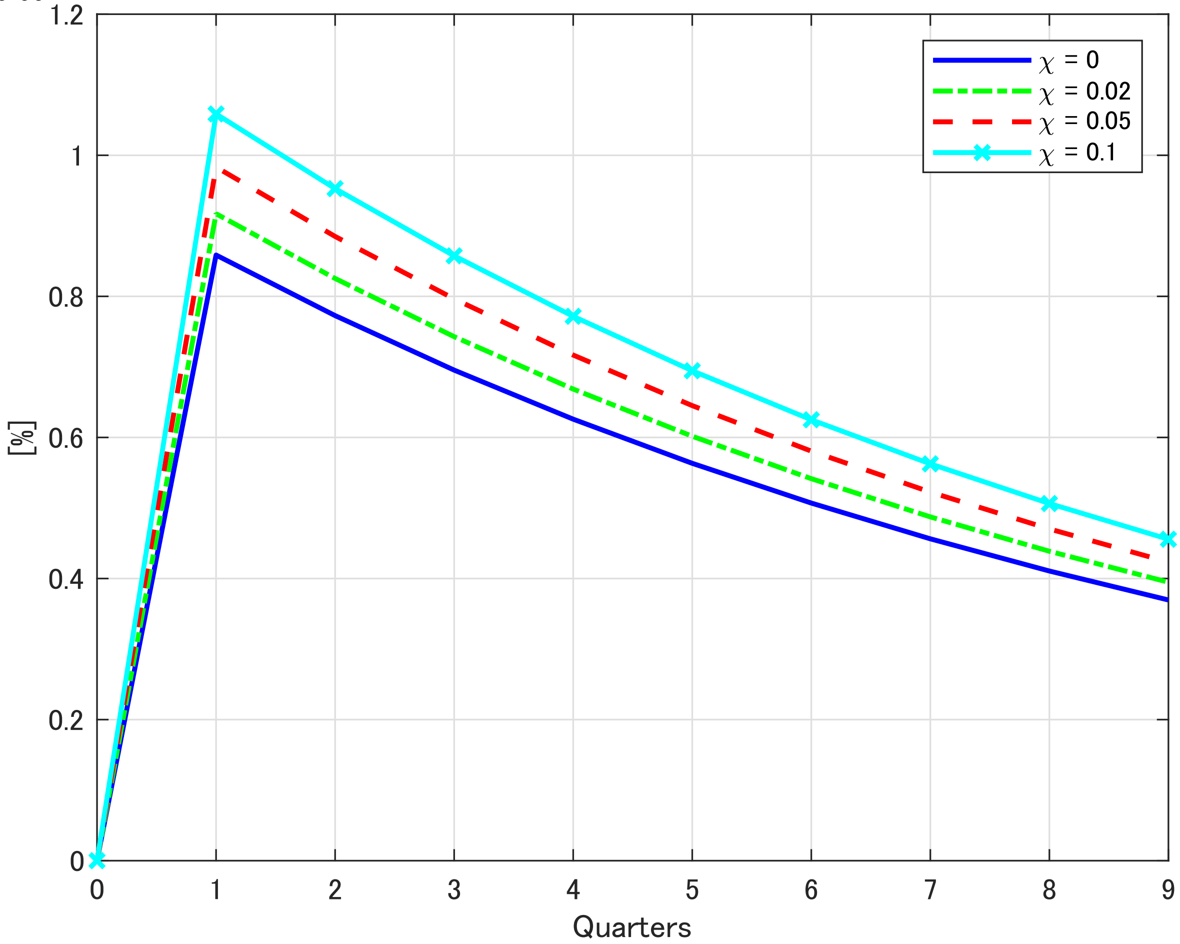


Figure 5: Impact response of the nominal interest rate to an inflation-targeting shock: The role of nominal price stickiness

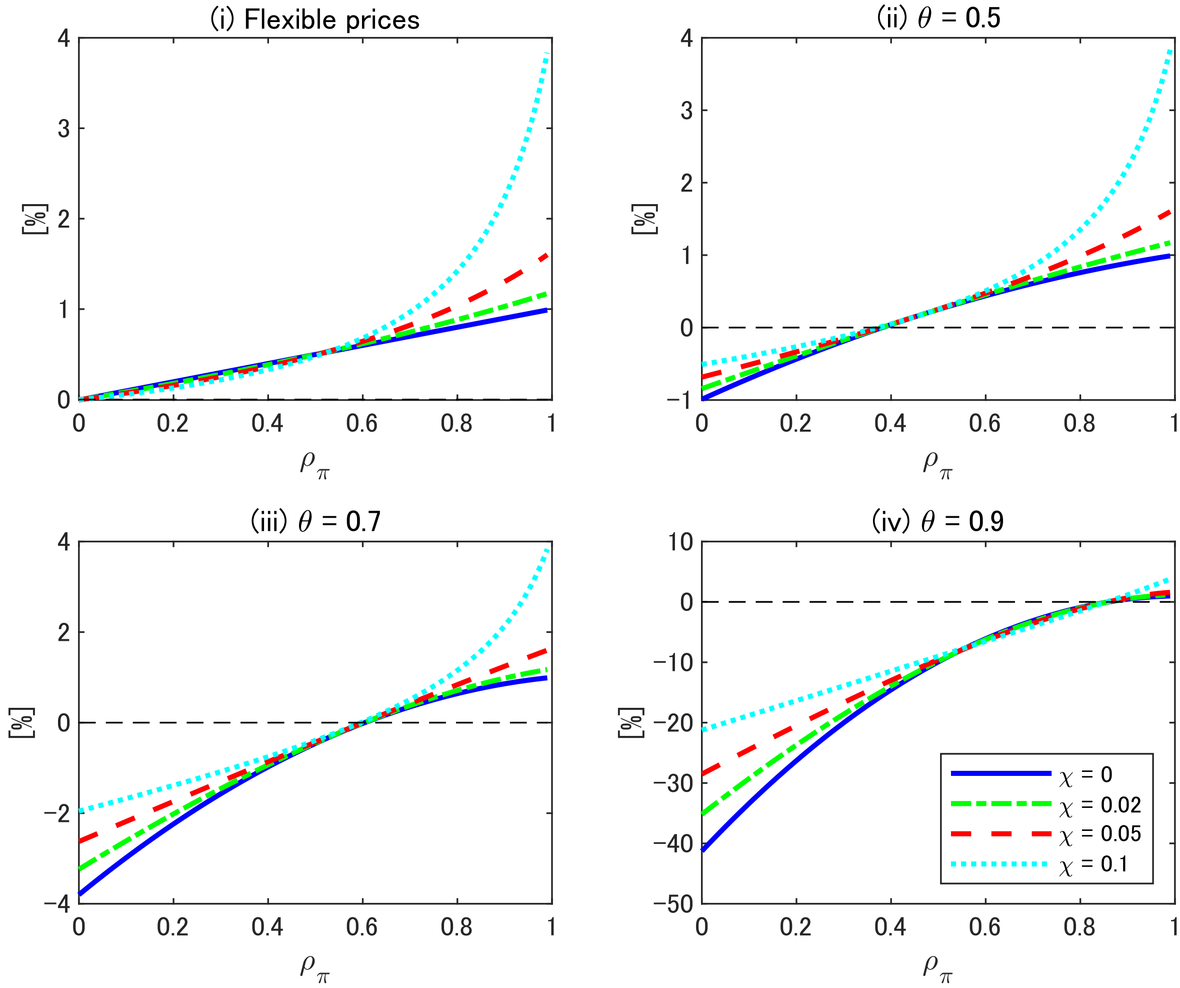
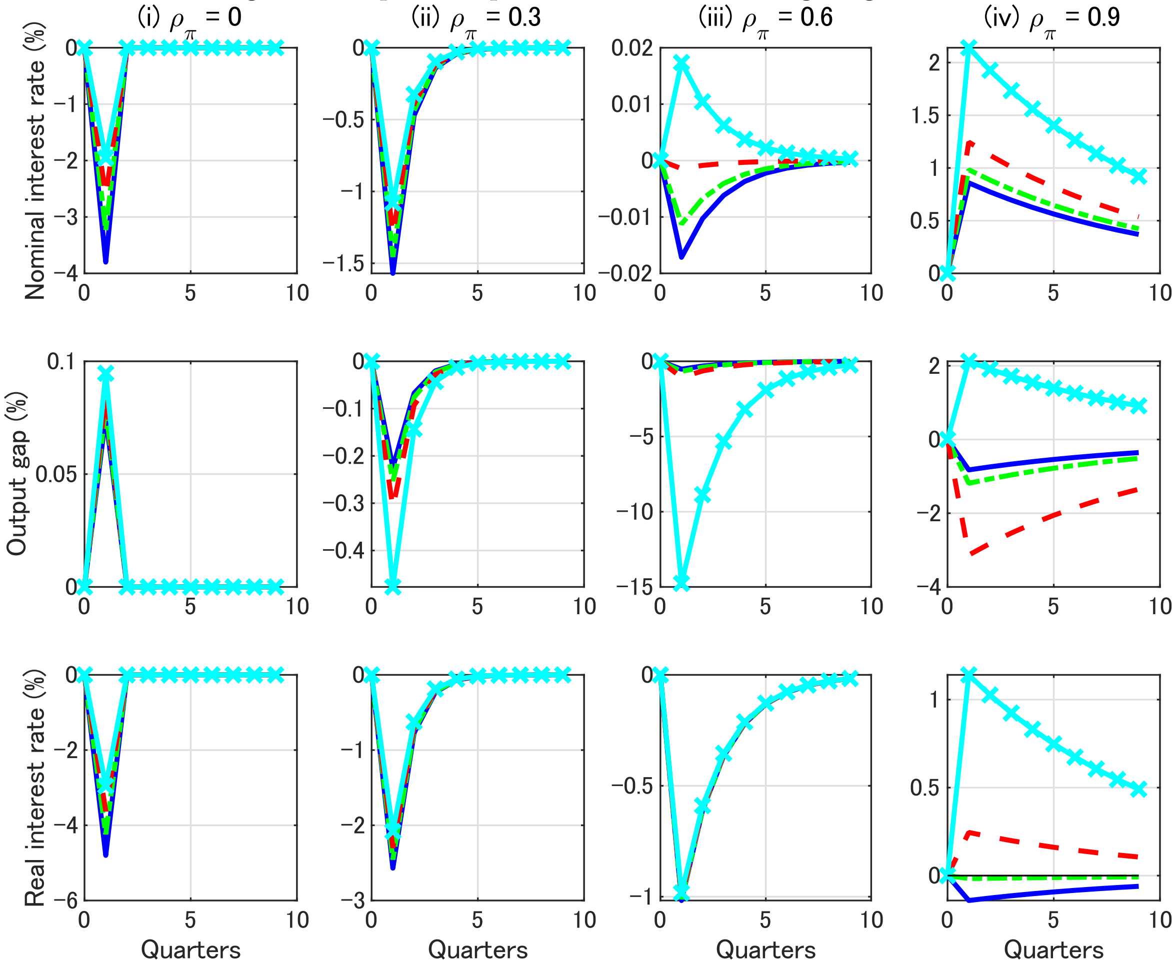


Figure 6: Impulse response to an inflation-targeting shock



Note: A solid line denotes $\chi = 0$, a dash-dotted line denotes $\chi = 0.02$, a dashed line denotes $\chi = 0.05$, and a line with (x) denotes $\chi = 0.1$, respectively.

Figure 7: The coefficient of i_t on π_t^* as a function of ρ_π and χ: The role of endogenous inflation persistence