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Trends in loan rates and monetary policy in a model with staggered loan contracts

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Abstract

This paper examines the effect of trends in loan rates (TLR) on monetary policy within the standard new Keynesian model. It defines TLR as a non-zero growth of the loan rate in the steady state. We find that the TLR significantly affects equilibrium determinacy and monetary policy transmission through fluctuations in loan rate dispersion. While equilibrium determinacy is unaffected by smaller values of a TLR, larger values render the rational expectation equilibrium indeterminate. Determinacy conditions under a TLR depend on specifications of monetary policy rules. Since time series data support larger values of a TLR, we suggest them as alternative explanations of inflation of the 1970s and 1990s.

Keywords: Trends in loan rates; Loan rate curve; Cost channel; Monetary policy rules; Determinacy;

JEL classifications: E52; E58

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1 Introduction

The ancestral new Keynesian model (NKM) with a cost channel often assumes incomplete pass-through between policy rates and loan rates (Ravenna and Walsh, 2006; Chowdhury, Hoffmann, and Schabert, 2006; Tillmann, 2008).[1] However, previous studies do not assume sluggish changes in loan rates. Several studies show empirically that loan rates are characterized by sluggish movement during economic shocks (Berger and Udell, 1992; de Bondt and Mojon, 2005; de Bondt, 2005; Hofmann and Mizen, 2004; Sander and Kleimerier, 2004). Such sluggish movement is the source of the incomplete pass-through of loan rates (Berger and Udell, 1992; Huelsewig et al., 2006; Henzel, et al., 2009).[2]

Huelsewig, et al. (2006), Kobayashi (2008), and Teranishi (2015) introduced incomplete pass-through of loan rates to the standard NKM by assuming staggered loan rates. Huelsewig, et al. (2006) empirically assessed loan rate stickiness in a dynamic stochastic general equilibrium model with staggered loan contracts. Kobayashi (2008) and Teranishi (2015) analyzed the relation between optimal monetary policy and a staggered loan contract. These studies have derived the dynamic loan rate curve by log-linearizing optimal conditions of private banks around a *zero trend growth of loan rates in the steady state*.

Figure 1 plots the time-series data for loan rates in the United States, the United Kingdom, and Japan. It indicates evident upward and downward trends and that average loan rates from the 1970s to the 1980s exceeded 10% on average in advanced economies. Our study is motivated by this evidence. Huelsewig, et al. (2006), Kobayashi (2008), and Teranishi (2015) derived loan rate curves by presuming the trend in loan rates as *zero*. We label trends in loan rates (TLR) as *non-zero growth of loan rates in the steady state*. Ascari and Ropele (2005), Cogley and Sbordone (2008), and Ascari and Sbordone

[1]The presence of the cost channel can be regarded as the source of the price puzzle (Barth and Ramey, 2001; Chowdhury et al., 2006; Castelnuovo, 2007). Ida (2014) studied how sluggish movements in loan rates affect the condition that generates the price puzzle in the standard NKM.

[2]Kwapil and Scharlar (2010) introduced an incomplete pass-through of loan and deposit rates in a sticky price model.

(2014) noted that the presence of trend inflation significantly influences monetary policy analysis. The contribution of this paper is to apply the idea of trend inflation to loan rate dynamics. To the best of our knowledge, there are no studies how the TLR alter equilibrium determinacy and monetary policy transmission.

[Figure 1]

We show that the TLR considerably reconfigures the loan rate curve, defeating the assumption of the a zero TLR, loan rate dynamics are more complicated than the zero TLR. As the TLR increases, loan rate dynamics become more forward-looking. In particular, the loan rate curve is affected by the output gap unless the TLR is zero. These results are in contrast with Hueisewig, et al. (2006), Kobayashi (2008), and Teranishi (2015), who derived the loan rate curve around a zero TLR. As long as the TLR is not zero, loan rate dispersion alters the relative loan rate between private banks. Changes in relative loan rates induce changes in firms' relative demand for loans. In a cost channel scenario, changes in relative demand for loans prompt changes in relative labor demand, which generates fluctuation in output. Therefore, loan rate dispersion derived from a *non-zero* TLR causes output fluctuation.

We explore how a non-zero TLR affects equilibrium dynamics and monetary policy. First, we find that equilibrium determinacy is easily achieved if the TLR remains below 5%. If it exceeds 5%, regions of indeterminacy expand as loan rates become increasingly sticky given greater interest rate elasticity of demand for individual loans. Larger values of elasticity imply a market-based financial system wherein loan rates evolve instantaneously in accord with market rates (Huelsewig et al., 2006). Larger values of the TLR generate larger fluctuations in loan rate dispersion. These fluctuations may be amplified by a greater interest rate elasticity of loan demand. Accordingly, severe loan rate stickiness conflicts with a market-based financial system when the TLR is not zero.

Second, we explore how monetary policy rules affect equilibrium indeterminacy when a TLR exists.[3] Under a contemporaneous policy rule, a higher TLR forces central banks

[3]Surico (2008) and Llosa and Tuesta (2009) discussed equilibrium determinacy in the canonial NKM

to respond stronger to the inflation rate if they respond strongly to the output gap. Given a higher TLR, determinacy regions shrink more under a lagged policy rule than a contemporaneous policy rule. Thus, strong responses of the inflation and output gap make REE indeterminate. Interestingly, combinations of upper bounds for inflation stabilization and lower bounds for output gap stabilization can achieve a unique REE if central banks react strongly to the output gap.

Third, under a forward-looking policy rule, a weaker response to inflation requires severe upper bounds to stabilize output gaps, whereas a stronger response against inflation in the rule can relax the upper bounds for stabilizing output gaps. Our results reveal that the TLR exacerbates the indeterminacy problem more than the standard cost channel model.

We demonstrate that the TLR quantitatively affects the volatilities of key macro variables. When loan rates are stickier, higher values of the TLR significantly amplify fluctuations in macrovariables. Alongside loan rate stickiness, the effect of the TLR on the economy depends on the specification of the banking sector. Under bank-based financial systems, the real economy is unaffected by values for the TLR. When financial systems are closed to market-based rates, however, a higher TLR amplifies the volatilities of inflation, the output gap, and the loan rate. Although several studies highlight the importance of staggered loan contracts and relationship banking, they might not fully explain inflation fluctuations and the output gap during the 1970s.

We address how the TLR can explain volatile movements in macro variables during the 1970s and 1980s as well as staggered loan contracts and relationship banking. Clarida et al. (2000) and Coibion and Gorodnichenko (2011) pointed out that the economy was likely to be indeterminate because the standard Taylor principle, which requires the central bank to respond with a more than one for one increase in the interest rate when inflation increases, was not satisfied during the 1970s.[4] However, to the best of our

with a cost channel. We focus on equilibrium determinacy in the standard NKM with both staggered loan contracts and the TLR.

[4] More precisely, Coibion and Gorodnichenko (2011) argue that the economic instability of the period before the U.S. great moderation was caused by a combination of high trend inflation and a mild policy

knowledge, no previous studies have focused on the determinacy condition in a model with a staggered loan contract with the TLR.

This paper proceeds as follows. Section 2 describes the standard NKM with a TLR. Apart from the introduction of TLR, the model is of a standard NKM. Therefore, most of Section 2 is devoted to explaining the loan rate curve under the TLR. Section 3 calibrates the study's deep parameters. Section 4 presents primary results. Section 4.1 examines the determinate equilibrium with a TLR. Section 5 explores impulse response analysis and second moment properties. Section 6 presents the conclusion. The Appendix explains the derivation of the loan rate curve with a TLR.

2 Model

Except for TLR, our model adopts the standard NKM framework with staggered loan contracts (Kobayashi, 2008; Huelsewig, Mayer and Wollmershaeuser, 2006; Teranishi, 2015). The economy contains households, private banks, and a monetary authority. After briefly describing the household and firm sectors, we focus on deriving the loan rate curve in accordance with introduction of TLR.

2.1 Households

An infinitely-lived representative household maximizes the following inter-temporal utility:

$$E_t \sum_{t=0}^{\infty} \beta^j \left(\frac{C_{t+j}^{1-\sigma}}{1-\sigma} - \frac{N_{t+j}^{1+\eta}}{1+\eta} \right), \tag{1}$$

where C_t is the consumption and N_t is the household labor supply. β denotes the discount factor, and σ is the relative risk aversion coefficient for consumption. η is the inverse of the Frisch's elasticity of labor supply. Finally, E_t represents the expectations conditional on period t.

response.

The household budget constraint is given by

$$P_tC_t + D_t = W_tN_t + R_{t-1}D_{t-1} + \Gamma_t, \tag{2}$$

where D_t represents the deposits in private banks; W_t is the nominal wage rate; and Γ_t is the profit from the firms and banks distributed at the end of period t.

The optimality condition associated with the household maximization problem leads to a dynamic IS curve derived from the household's Euler equation for optimal consumption. It is given by

$$x_t = E_tx_{t+1} - \sigma^{-1}(r_t - E_t\pi_{t+1} - \bar{r}r_t), \tag{3}$$

where $x_t = y_t - y_t^n$ defines the output gap. Lower case variables denote a log deviation from the steady state. $z_t = \log(Z_t/\bar{Z})$ expresses a log-linearized variable around the steady state. $\bar{Z}$ denotes a steady-state value. y_t represents the log-deviation of actual output; and y_t^n is the log-deviation of the natural rate of output.[5] π_t is the inflation rate, and finally, $\bar{r}r_t$ is the natural rate of interest, representing the real interest rate in a flexible price equilibrium. The natural rate of interest is defined by

$$\bar{r}r_t = \sigma(E_ty_{t+1}^n - y_t^n).$$

2.2 Firms

The firm sector parallels the standard NKM. Firms face monopolistic competition and set their prices according to the Calvo pricing rule. Following Calvo (1983), there exists price rigidity that a fraction of firms cannot adjust their prices each period. Firms that can revise their prices will consider uncertainty with respect to when they will next be able to adjust their prices. Moreover, under the cost channel, firms need to borrow working capital from financial intermediaries at lending rate R_t^L. Firm use labor supply as an input, and decreasing returns to scale characterize the production function given by $Y_t = A_tN_t^{(1-\alpha)}$. Parameter α is the degree of diminishing returns to scale in the

[5] See Ravenna and Walsh (2006), Kobayashi (2008), and Teranishi (2015) for a discussion and definition of the natural rate of output in a model with cost channels.

production function. A_t is an exogenous productivity disturbance, which follows an AR (1) process given by $\log(A_t) = \rho_a \log(A_{t-1}) + \epsilon_t^a$ with $0 \leq \rho_a < 1$.

When the cost channel is present, as derived by Ravenna and Walsh (2006), the inflation dynamics are depicted by the new Keynesian Phillips curve (NKPC):

$$\pi_t = \beta E_t \pi_{t+1} + \kappa(\vartheta x_t + \delta r_t^l), \tag{4}$$

where $\kappa = (1-\omega)(1-\omega\beta)/\omega$ and $\vartheta = [\alpha + \eta + \sigma(1-\alpha)]/(1-\alpha)$. The parameter ω is Calvo's lottery. As argued in Tillmann (2009) and Demirel (2013), there is a cost channel when $\delta = 1$. We assume a full cost channel (i.e., $\delta = 1$). Unlike the standard NKM, inclusion of a cost channel augments the term for lending rate in the NKPC.

2.3 Private banks

As in Huelsewig, et al. (2006), Henzel, et al. (2009), Kobayashi (2008), and Teranishi (2015), there is a continuum of individual private banks. Following Huelsewig, et al. (2006) and Henzel, et al. (2009), we assume that private bank i operates within a bank-based financial system and faces the following loan demand curve:

$$L_t(i) = \left(\frac{R_t^L(i)}{R_t^L} \right)^{-\zeta} L_t, \tag{5}$$

with

$$L_t = \left[\int_0^1 L_t(i)^{\frac{\zeta-1}{\zeta}} di \right]^{\frac{\zeta}{\zeta-1}}, \tag{6}$$

$$R_t^L = \left[\int_0^1 R_t^L(i)^{1-\zeta} di \right]^{\frac{1}{1-\zeta}}, \tag{7}$$

where ζ is the interest rate elasticity of demand for individual loan $L_t(i)$, $R_t^L(i)$ is the gross interest rate for $L_t(i)$, and L_t is the aggregate lending of the banking sector. As in Huelsewig, et al. (2006) and Henzel et al. (2009), parameter ζ represents the degree of relationship banking between firms and private banks.[6] Its higher values imply that

[6] See Berger and Udell (1992), Scharler (2008), Huelsewig, et al. (2006), and Henzel et al. (2009) for a detailed discussion of bank-based financial systems in explaining dynamics of the loan rate.

the firms abandon relationships with their private banks if loan rates change. Therefore, higher values for ζ force the structure of the loan market toward a market-based system characterized by perfect competition in the loan market.

As mentioned in the Introduction, a bank-based financial system motivates sticky loan rates, a consideration we incorporate by presuming that private banks in a customer market experience nominal friction (Calvo, 1983). During each period, fraction $1-\tau$ of private banks optimally resets loan rates, whereas fraction τ must keep them unchanged. An aggregate loan rate is given by

$$R_t^L = [(1-\tau)(R_t^{L*})^{1-\zeta} + \tau(R_{t-1}^L)^{1-\zeta}]^{\frac{1}{1-\zeta}}, \tag{8}$$

where R_t^{L*} is the loan rate that banks set optimally at period t. The clearing condition of the loan market is given by $W_t N_t / P_t = L_t$.

The maximization problem for private bank i is characterized by

$$E_t \sum_{j=0}^{\infty} \tau^j Q_{t,t+j} \left[M_{t+j} \left(\frac{R_t^{L*}}{R_{t+j}^L} \right)^{1-\zeta} R_{t+j}^L - R_{t+j} \left(\frac{R_t^{L*}}{R_{t+j}^L} \right)^{-\zeta} \right] L_{t+j}, \tag{9}$$

where $Q_{t,t+j}$ denotes the stochastic discount factor. As in Teranishi (2015), M_t is an exogenous disturbance from time-varying subsidies. Like Teranishi (2015), we assume that M_t takes unity in the steady state.

The first-order condition of Equation (9) leads to the optimal condition for the loan rate:

$$E_t \sum_{j=0}^{\infty} (\tau\beta)^j \frac{Y_{t+j}^{1-\sigma}}{Y_t^{1-\sigma}} \left[(1-\zeta) \left(\frac{R_t^{L*}}{R_{t+j}^L} \right)^{\zeta} + \zeta M_{t+j} R_{t+j} \left(\frac{R_t^{L*}}{R_{t+j}^L} \right)^{-\zeta-1} \left(\frac{R_{t+j}}{R_{t+j}^L} \right) \right] L_{t+j} = 0. \tag{10}$$

Equation (10) can be rewritten as

$$\frac{R_t^{L*}}{R_t^L} = \frac{\zeta}{\zeta - 1} \frac{F_t^L}{K_t^L}, \tag{11}$$

where

$$F_t^L \equiv E_t \sum_{j=0}^{\infty} (\tau\beta)^j Y_{t+j}^{-\sigma} M_{t+j} R_{t+j} (R_{t+j}^L)^{-1} L_{t+j} \mathcal{R}_{t+j}^{\zeta}, \tag{12}$$

$$K_t^L \equiv E_t \sum_{j=0}^{\infty} (\tau\beta)^j Y_{t+j}^{-\sigma} L_{t+j} \mathcal{R}_{t+j}^{\zeta-1}, \tag{13}$$

$$\mathcal{R}_{t+j} \equiv \frac{R_{t+1}^L}{R_t^L} \frac{R_{t+2}^L}{R_{t+1}^L} \cdots \frac{R_{t+j}^L}{R_{t+j-1}^L}. \tag{14}$$

$\mathcal{R}_{t+j}$ represents the term for the TLR, the value of which we assume non-zero.[7] Log-linearization of Equations (8) and (9) under a non-zero TLR produces the following dynamics:[8]

$$\hat{R}_t^L = \psi_1 x_t + \psi_2 \hat{R}_t + \psi_3 E_t \hat{R}_{t+1}^L + \psi_4 \hat{R}_{t-1}^L + \psi_5 E_t \phi_{t+1} + \nu_t, \tag{15}$$

$$\phi_t = \mu_1 x_t + \mu_2 \hat{R}_t + \mu_3 \hat{R}_t^L + \mu_4 (\zeta E_t \hat{R}_{t+1}^L + E_t \phi_{t+1}) + \varepsilon_t. \tag{16}$$

Note that we re-define $\hat{F}_t^L$ as ϕ_t. Also, coefficients for Equations (15) and (16) are defined as follows:

$$\begin{aligned}
&\Gamma \equiv 1 - \tau\beta(r^g)^{\zeta-1}\left[(1-\tau(r^g)^{\zeta-1})((1-\zeta)r^g + \zeta) - r^g\right],\\
&\psi_1 \equiv \frac{\tau\beta(r^g)^{\zeta-1}(r^g-1)(1+\eta)}{\Gamma},\ \psi_2 \equiv \frac{(1-\tau(r^g)^{\zeta-1})(1-\tau\beta(r^g)^{\zeta})}{\Gamma},\\
&\psi_3 \equiv \frac{\tau\beta(r^g)^{\zeta-1}}{\Gamma},\ \psi_4 \equiv \frac{\tau(r^g)^{\zeta-1}}{\Gamma},\ \psi_5 \equiv \frac{(1-\tau(r^g))^{\zeta-1}\tau\beta(r^g)^{\zeta}(r^g-1)}{\Gamma},\\
&\mu_1 \equiv \frac{(1-\tau\beta(r^g)^{\zeta})(1+\eta)}{1-\alpha},\ \mu_2 \equiv 1-\tau\beta(r^g)^{\zeta},\ \mu_3 \equiv 1+\tau\beta(r^g)^{\zeta}(\zeta-1),\\
&\mu_4 \equiv \tau\beta(r^g)^{\zeta},\ \varepsilon_t \equiv (1-\tau\beta(r^g)^{\zeta})(1-\sigma)\hat{Y}_t^n,\ \nu_t \equiv \frac{(1-\tau(r^g)^{\zeta-1})}{\Gamma}\hat{M}_t,
\end{aligned}$$

where r^g denotes the trend loan rate and ν_t is an exogenous loan rate shock generated by time-varying subsides. Without the TLR (i.e., $r^g = 1$), the loan rate curve reduces to the standard curve derived by Kobayashi (2008), Huelsewig, et al. (2006), and Teranishi (2015).

Given a TLR, loan rate dispersion is no longer ignored, unlike the case where the TLR equals to zero. Log-linearized loan rate dispersion is given as

$$\hat{\Delta}_t^L = \frac{\tau(r^g)^{\zeta-1}}{1-\tau(r^g)^{\zeta-1}}(r^g-1)(\hat{R}_t^L - \hat{R}_{t-1}^L) + \tau(r^g)^{\zeta}\hat{\Delta}_{t-1}^L, \tag{17}$$

where $\Delta_t^L = \int_0^1 [(R_t^L(i))/R_t^L]^{-\zeta} di$ denotes the degree of loan rate dispersion, which is set to unity without a TLR. It follows from Equation (17) that loan rate dispersion disappears when $r^g = 1$.

[7] We assume that this value cannot be negative.

[8] The appendix provides for derivations of these equations.

Loan rate dispersion emerges as long as $r^g > 1$. The higher TLR induces a large fluctuation in loan rate dispersion. Loan rate dispersion generates changes in relative loan rate that disperse relative loan demand. According to loan market equilibrium conditions, changes in relative demand for individual loans alter aggregate supply. Consequently, the existence of the TLR allows for the presence of the output gap in Equations (15) and (16). We address the presence of the output gap in the loan rate curve that is disregarded by previous studies, which instead focus on the TLR set to zero.

As with trend inflation,[9] larger values for the TLR renders the loan rate curve more forward-looking via the effect of the auxiliary variable ϕ_t. This feature implies that future perspectives on the business cycle more dominantly affect dynamics of the current loan rate. Accordingly, we suggest that the presence of a higher TLR affects the mechanism transmitting structural shocks.

2.4 Monetary policy

To close the model, we specify central bank actions. Assuming that central banks simply follow a simple feedback rule that responds endogenously to inflation and the output gap, we obtain

$$r_t = \phi_\pi E_t \pi_{t+k} + \phi_x E_t x_{t+k} + e_t, \tag{18}$$

for $k = -1, 0, 1$. ϕ_π is the coefficient of inflation and ϕ_x is the coefficient of the output gap, e_t denotes a monetary policy shock. The monetary policy rule becomes forward-looking when $k = 1$ and backward-looking when $k = -1$.

3 Calibration

This section explains the calibrated parameters used in the paper. Parameters are based on those in the standard NKM. The degree of diminishing returns to scale in the production function (α) is set to 0.33. The discount factor β is set to 0.99 and the relative

[9]For a discussion of higher trend inflation forcing the NKPC to be more forward-looking, see Ascari and Ropele (2007).

risk aversion coefficient for consumption (σ) to 5.0.[10] The inverse of the Frisch elasticity of labor supply (η) is set to 2.0. Calvo lottery ω is set to 0.75.

Next, we explain the value of loan rate stickiness (τ). Kobayashi (2008) set its least value at 0.14 and largest at 0.42. Teranishi (2015) set loan rate stickiness to 0.66. Huelsewig et al. (2006) reported an estimation value of 0.36. Therefore, we select 0, 0.25, and 0.55 for loan rate stickiness. We set the interest rate elasticity of demand for individual loans to 7.88. Huelsewig, et al. (2006) shows that the estimated value of ζ is 3.5, which seems small compared with our study. We select alternative values for parameter ζ for sensitivity analyses.

To benchmark monetary policy rules, we set coefficients for inflation stabilization ϕ_π and for output gap stabilization ϕ_x to 1.5 and 0.5, respectively. The determinacy analyses explores how the TLR affects equilibrium determinacy under combinations of ϕ_π and ϕ_x.

Finally, we calibrate values for structural shocks.[11] Persistence of productivity shocks and its standard deviation are set to 0.9 and 0.02, respectively. Persistence of a monetary policy shock is set to 0.5, and the standard deviation for a policy shock is 0.25. The degree of persistence and standard deviation for a loan rate shock are set to 0.9 and 0.02, respectively.

4 Determinacy analysis

4.1 Effect of TLR on equilibrium determinacy

This section examines whether the TLR affects the equilibrium determinacy. Figure 2 plots determinacy regions with a combination of loan rate stickiness τ and degree of relationship banking ζ when the TLR changes. Without a TLR, a unique REE is achieved irrespective of combinations of τ and ζ. However, equilibrium indeterminacy

[10] Our results are unaffected by all values for parameter σ.

[11] Our substantial results are quantitatively and qualitatively unaffected by the following calibrated values for shocks.

occurs once a non-zero TLR is introduced into the model. Combining larger values for τ and ζ leads to equilibrium indeterminate. For instance, values above 0.75 for loan rate stickiness makes the REE indeterminate when ζ takes values above 6.0. This situation becomes more dominant as the TLR takes larger values. When the TLR is 10%, a stickier loan rate easily renders equilibrium indeterminate for larger values of ζ.

[Figure 2]

The intuition behind this result is as follows. Larger values for the TLR makes the loan rate dynamics more forward-looking. As shown in Equation (17), a higher TLR leads to fluctuation in loan rate dispersion. This outcome indicates that large changes in loan rate dispersion distort the relative loan rate among banks, which induces a change in individual demand for loans. If ζ takes smaller values, the banking system reflect the features of a bank-based financial system (Berger and Udell, 1992; Kaufmann and Scharler, 2009). Under that system, changes in loan rates are smoothed. Loan rate stickiness thus does not conflict with a bank-based financial system.[12] Put differently, economies with bank-based financial systems can achieve a unique REE even when loan rates stagger in the presence of a higher TLR. We highlight that smaller values of ζ can prevent a higher TLR from generating equilibrium indeterminacy.

Conversely, a higher TLR renders REE indeterminate as ζ ascends in value, even under staggered loan contracts. It follows from Figure 2 that an increase in ζ expands indeterminacy regions. For instance, if $\zeta = 10$, the TLR of 10% generates sunspot equilibrium when the loan rate becomes more flexible. Unlike smaller values for ζ, larger values imply that a market-based financial system generates fluctuations in the loan rate. As a higher TLR leads to fluctuations in loan rate dispersion, larger values for ζ cause a large fluctuations in loan rates. Central banks cannot pin down a unique REE in such situations.

Figure 2 also shows that combinations of higher values for τ and ζ create equilibrium indeterminacy because sticky loan rates appear inconsistent with larger values of ζ in

[12] See Berger and Udell (1992), Freixas and Rochet (2008), and Ida (2014) for a detailed discussion of modeling financial systems.

the case of a higher TLR. Larger values of ζ are nearer to a market-based financial system where loan rates accords instantaneously with market rates (Huelsewig et al. 2006). As noted, larger values for the TLR force loan rate dynamics to be more forward-looking. Larger values for the TLR generate large fluctuations in loan rate dispersion, which are amplified when loan demand is more sensitive to interest rates. Stickiness prevents fluctuations in the loan rate itself. Because severe stickiness conflicts with a market-based financial system, a higher TLR makes REE more indeterminate.

4.2 TLR and monetary policy rules

Now we investigate how specifications of monetary policy rules change equilibrium determinacy under a TLR.[13] A contemporaneous monetary policy rule, which reacts to current inflation and the current output gap, is our benchmark for analysis. As shown in Figure 3, central banks can easily attain equilibrium determinacy when inflation stabilization in the policy rule ϕ_π exceeds above 2.0 if the TLR is below 5%. That is not the case when it reaches 10%. Figure 3 shows that a larger weighting for output gap stabilization leads to equilibrium indeterminacy unless central banks respond to the inflation rate strongly. For instance, it must set ϕ_π above 4.0 when ϕ_x is set to 6.0. Also, the central bank must set ϕ_π at a value above 6.0 when ϕ_x is set to 10 under the policy rule. Under a contemporanous policy rule, therefore, a higher TLR forces a stronger central bank response to inflation if it responds strongly to the output gap (Figure 3).

[Figure 3]

An increase in policy rate exerts two effects on inflation through demand and cost channels. When the latter channel dominates the former, monetary tightening may initiate declines in the real interest rate, producing a sunspot equilibrium. As Llosa and Tuesta (2009) presented, the response to inflation under a contemporaneous rule must satisfy the Taylor principle, whereas it is restricted by the upper bounds. In addition,

[13] See Surico (2008) and Llosa and Tuesta (2009) for a detailed discussion of the uniqueness of REE under a cost channel. Their studies focused on the cost channel that abstracts a staggered loan contract.

the response to the output gap is restrictive in the case of a cost channel. A higher TLR strengthens the cost channel by making the loan rate curve more forward-looking. Therefore, central bank's response to inflation is more restrictive when the TLR is higher. Simultaneously, the response to the output gap is limited as the TLR acquires larger values.

[Figure 4]

Next, we consider that central banks adopt a lagged policy reaction to inflation and the output gap. As McCallum (1999) stressed, lagged policy acknowledges that central banks cannot instantly observe inflation and the output gap because they may lack complete information about them. Figure 4 shows that the determinacy regions under a lagged policy rule are more complicated than under a contemporaneous policy. In particular, when $r^g = 10\%$, determinacy regions apparently shrink under a lagged vs a contemporaneous policy rule. Thus, a combination of higher values for both ϕ_π and ϕ_x renders the REE indeterminate. Interestingly, the presence of upper bounds for ϕ_π and lower bounds for ϕ_x makes REE determinate if central banks respond to the output gap more strongly. That is, to attain unique REE, central banks should react strongly to inflation if it seeks moderate stabilization of the output gap.

Since a lagged policy reacts to lagged endogenous variables, central banks may overreact to fluctuation in current endogenous variables. Central banks that follow a lagged policy rule fail to raise the real interest rate even if a higher TLR that forces the loan rate curve to be forward-looking magnifies the cost channel. Therefore, such a policy reaction would be undesirable for fully stabilizing a sunspot shock. Surico (2008) illustrated that compared with a contemporaneous rule, a backward-looking rule can expand the determinacy regions in the case of a cost channel.[14] Unlike Surico (2008), we show that central banks' response to endogenous variables is more restrictive under a backward-looking policy rule while facing a higher TLR.

Finally, we consider a forward-looking monetary policy rule in the sense that central banks respond to expected inflation and an expected output gap. Figure 5 shows that

[14]Surico (2008) does not consider the degree of the incomplete pass-through of loan rate.

the determinacy condition requires both upper and lower bounds for response to the output gap.[15] However, lower bounds for an inflation response are required to retain unique REE. According to Llosa and Tuesta (2009), modest responses to inflation and the output gap attain a unique REE and E-stability under adoptive learning. Except for the E-stability condition, our results differ from theirs. We address that the stronger response to inflation combined with a modest response to the output gap, attains a unique REE when the TLR takes higher values.

[Figure 5]

Notably, our claim is more severe when $r^g = 10\%$. Central banks should react to inflation more strongly if they respond aggressively to output gaps. As shown in Figure 5, when $r^g = 10\%$, larger values for ϕ_x easily lead to sunspot equilibria if central banks set ϕ_π to less than 5.0. In other words, the threshold for reacting to inflation is roughly 5.0 when central banks consider whether to introduce a strong reaction to an output gap under a forward-looking rule. Thus, on the one hand, central banks impose on a severe upper bound for stabilizing the output gap if they follow a policy rule with $\phi_\pi < 5$. They require the upper bound for ϕ_x to retain unique REE with a higher TLR. On the other hand, the upper bound for ϕ_x is counteracted if $\phi_\pi > 5$.

Since a forward-looking rule responds to forecasts of inflation and the output gap, overreaction to these variables makes REE indeterminate (Bernanke and Woodford, 1997). Hence, responses to these forward-looking variables are restricted by lower and upper bounds, as shown by Bullard and Mitra (2002). Llosa and Tuesta (2009) demonstrated that the presence of a cost channel severely restricts central banks' responses to forecasts of inflation and output gaps. Compared with these earlier studies, we address that responses to expected inflation and expected output gap are more restrictive because a higher TLR strengthens the cost channel induced by staggered loan contracts.

[15] For instance, see Bullard and Mitra (2002), Surico (2008), and Llosa and Tuesta (2009) for the case of a standard cost channel model.

5 Impulse response analyses and second moment properties

This section shows the results of impulse response analysis and second moment properties. We have shown that the TLR affects equilibrium determinacy. Therefore, it should affect macroeconomic dynamics quantitatively. We first show impulse response analyses results for a loan rate and productivity shock. Then, we calculate second moment properties of key macrovariables under parameterizations of the TLR.

5.1 Impulse response analyses

Figure 6 illustrates the impulse response function to an exogenous loan rate shock. As several studies indicate, the cost channel acts as a cost-push shock to generate a tradeoff between inflation and output stabilization.[16] Even without a TLR, a loan rate shock situates a wedge between stabilizing inflation and output gaps. In contrast to the cost channel model without a TLR, our results underscore that a higher TLR deteriorates that tradeoff. A higher TLR creates a severe decline in relative demand for loans, causing a large fluctuation in loan rates. The amplified increase in the loan rate generates a huge decline in the output gap. On the one hand, the drop in the output gap induces a decline in the inflation rate through the NKPC. On the other hand, higher loan rates tighten the real marginal cost and increase inflation. If the latter effects dominate, the TLR magnifies the cost channel effect of the interest rate.

[Figure 6]

Figure 7 shows the impulse-response function after a positive productivity shock that raises output and subdues inflation. Diminishing inflation prompts a lower policy rate, which lowers the loan rate. When a higher TLR exists, firms normally expect a positive productivity shock to reduce loan rates because the TLR makes the loan rate curve

[16] Ravenna and Walsh (2006) discussed a policy tradeoff between inflation and the output gap when a cost channel is present.

more forward-looking. Hence, further reduction in loan rates stimulates loan demand and eventually a boom in output. The inflation rate also appears unaffected by changes in the TLR. This outcome occurs because the increase in the output gap partially offsets the decline in real marginal cost induced by lower loan rate.

[Figure 7]

5.2 Second moment properties on key macro variables

We calculate the second moment properties of key macrovariables under several values for the TLR. First, we focus on loan rate stickiness given flexible and sticky loan rates. We set τ to 0.25 for the former and 0.55 for the latter. Under a flexible loan rate, several macrovariables in Table 1 seem quantitatively unaffected by changes in the TLR. Rather, volatilities for macrovariables seem to decline when its value are higher.

[Table 1]

As shown in Table 2, when loan rates are sticky, however, an increase in the TLR significantly magnifies the volatilities of indicated macrovariables. For instance, when the TLR is 10%, the volatility of the output gap is roughly double the case without it. In particular, the volatility of loan rate dispersion is approximately seven times when greater when $r^g = 5\%$. Many studies empirically support the phenomenon of loan rate stickiness, but we address the presence of a TLR by observing time-series data. Because a TLR amplifies the volatilities of inflation and the output gap, that might partially explain the inflation, output gap, and loan rates during the 1970s and 1980s.

[Table 2]

We also examine whether degrees of relationship banking (ζ) quantitatively affect the volatilities of indicated macro-variables. As confirmed earlier, relationship banking affects equilibrium determinacy. Therefore, the value of ζ should change the quantitative effects of the TLR on key macrovariables. Table 3 shows how it affects indicated macrovariables given smaller values of ζ. As mentioned earlier, smaller values of ζ mean that banking systems mirror a bank-based financial system, which smoothens loan rates. Therefore, even if loan rates are sticky, a bank-based financial system tends to counteract fluctuations in key macrovariables derived from the TLR. Put differently, relationship banking restrains macroeconomic fluctuations regardless of values for the TLR. Except for TLRs, this result endorses previous studies (Berger and Udell, 1992; Scharler, 2008).

[Table 3]

When financial systems approximate a market-based system, however, a higher TLR enlarges the volatilities of inflation, the output gap, and the loan rate. Figure 8 shows that the effect of a loan rate shock on the real economy is amplified as financial systems are closer to a market-based one.[17] In particular, as parameter ζ takes larger values, the loan rate shock generates a more severe tradeoff between inflation and the output gap.

[Table 4]

Previous studies have addressed the importance of staggered loan contracts and relationship banking during the 1970s and 1990s. However, our results imply that the standard cost channel model that incorporates both cannot fully explain that era's volatile inflation and output gap. We offer an alternative explanation for those phenomena: the significant role of the TLR.

[Figure 8]

6 Conclusion

We have examined how the TLR affects monetary policy in the standard NKM. In doing so, we departed from earlier studies that examine monetary policy under a staggered loan contract but assume a TLR of zero. Their assumption is inconsistent with time-series data from advanced economies.

[17] We assume that the TLR is of 5% in calculating the impulse response to retain the unique REE.

Our results show that the TLR alters the shape of the loan rate curve and affects equilibrium determinacy and monetary policy through fluctuations in loan rate dispersion. The results indicate that equilibrium determinacy is easily attainable as long as the TLR is below 5%. If it reaches 10%, indeterminacy regions expand as loan rates become stickier and the interest rate elasticity of loan demand intensifies.

We have also explored how monetary policy rules affect equilibrium indeterminacy under a TLR. First, when central banks obey a contemporaneous policy rule, a higher TLR forces them to respond to inflation as vigorously as they respond to the output gap. Second, with a higher TLR, determinacy regions shrink more under a lagged policy rule than under a contemporaneous policy rule. Combining stronger responses to inflation and the output gap renders REE indeterminate. Under a lagged policy rule, a unique REE requires upper bounds for the inflation response and lower bounds for the output gap response. Third, under a forward-looking policy rule, a weaker response to inflation requires a severe upper bound for responding to the output gap, whereas a stronger response can relax the upper bound to stabilize the coefficient of the output gap.

The results also indicate that the TLR quantitatively affects the volatilities of key macrovariables. With a stickier loan rate, a higher value for the TLR significantly magnifies the fluctuations in macrovariables. Alongside loan rate stickiness, the economic effect of the TLR depends on the degree of relationship banking. In bank-based financial systems, the real economy is unaffected by all values for the TLR. When financial systems are nearly market-based, however, a higher TLR amplifies the volatilities of inflation, the output gap, and the loan rate.

Several studies indicate the importance of staggered loan contracts and relationship banking. Our results imply that neither fully explains fluctuations in inflation and the output gap during the 1970s and 1990s. Some studies also argued that the economy was likely to be indeterminate because monetary policy rules did not satisfy the Taylor principle in the 1970s. In contrast to these studies, we have proposed the TLR as an alternative explanation for that era's volatile macrovariables.

Our results suggest future studies. As noted, we focus on the case for equilibrium determinacy. As stressed in earlier studies, it is also important to envision how central banks should conduct monetary policy when equilibrium deviates temporarily from REE. Whether the economy again achieves REE under a learning process depends greatly on the E-stability condition (Evans and Honkapohja, 2001; Bullard and Mitra, 2002; Evans and Honkapohja, 2003; Llosa and Tuesta, 2009). Future studies should investigate how central banks that cross-check their monetary policies may achieve E-stability and a unique REE under learning.

Furthermore, we have focused on simple instrument rules that future studies may extend to optimal monetary policy. To do so, they need a well-defined loss function, which is derived from the second-order approximation of household utility. For instance, in a standard staggered loan contract model, Kobayashi (2008) and Teranishi (2015) derive central banks' loss function by manipulating the second-order approximation of household utility. However, it may be interesting to assess how the presence of a TLR shapes central banks' loss function.[18]

Acknowlegements

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A Appendix: derivation of the generalized loan rate curve

This section derives a detailed derivation of the loan rate curve when the TLR is present. The log-linearization of Equation (11) is given by

$$\hat{q}_t^L = \hat{F}_t^L - \hat{K}_t^L, \tag{A.1}$$

[18] Alves (2014) derived a well-defined central bank's loss function from second-order approximations of the household utility function given non-zero trend inflation. We may apply his technique to cases featuring the TLR.

Next, the aggregate loan rate (8) is log-linearized

$$\hat{q}_t^L = \frac{\tau (r^g)^{\zeta-1}}{1-\tau (r^g)^{\zeta-1}} r_t^g, \tag{A.2}$$

where $r_t^g = \hat{R}_t^L - \hat{R}_{t-1}^L$.Log-linearization of K_t^L and F_t^L is given as follows:

$$\hat{F}_t^L = (1-\tau\beta(r^g)^{\zeta})[\hat{L}_t - \sigma\hat{Y}_t - (\hat{R}_t^L - \hat{R}_t) + \hat{M}_t] + \tau\beta(r^g)^{\zeta}(\zeta E_t \hat{r}_{g,t+1} + E_t \hat{F}_{t+1}^L), \tag{A.3}$$

$$\hat{K}_t^L = (1-\tau\beta(r^g)^{\zeta-1})(\hat{L}_t - \sigma\hat{Y}_t) + \tau\beta(r^g)^{\zeta-1}[(\zeta-1)E_t \hat{r}_{g,t+1} + E_t \hat{K}_{t+1}^L]. \tag{A.4}$$

Substituting Equations (A.2)-(A.4) into Equation (A.1) obtains

$$\begin{aligned}
&\frac{1+\tau\beta(r^g)^{\zeta-1}[(1-\tau(r^g)^{\zeta-1})((1-\zeta)r^g+\zeta)-1]}{1-\tau(r^g)^{\zeta-1}}\hat{R}_t^L \\
&= \tau\beta(r^g)^{\zeta-1}(r^g-1)[(1-\sigma)\hat{Y}_t + (\hat{L}_t - \hat{Y}_t)] + (1-\tau\beta(r^g)^{\zeta})\hat{R}_t + \tau\beta(r^g)^{\zeta-1}(r^g-1)E_t\hat{F}_{t+1}^L \\
&+ \frac{\tau\beta(r^g)^{\zeta-1}}{1-\tau(r^g)^{\zeta-1}}[\zeta(r^g-1)(1-\tau(r^g)^{\zeta-1})+1]E_t\hat{R}_{t+1}^L + \frac{\tau(r^g)^{\zeta-1}}{1-\tau(r^g)^{\zeta-1}}\hat{R}_{t-1}^L + (1-\tau(r^g)^{\zeta-1})\hat{M}_t.
\end{aligned} \tag{A.5}$$

Using the equilibrium condition for the loan market, $\hat{L}_t - \hat{Y}_t$ can be rewritten as

$$\hat{L}_t - \hat{Y}_t = \hat{N}_t + \hat{w}_t - [A_t + (1-\alpha)\hat{N}_t] = \hat{\varphi}_t - \hat{R}_t^L, \tag{A.6}$$

where $\hat{w}_t$ is the real wage rate and $\hat{\varphi}_t$ denotes the real marginal cost for the firm. Substituting this equation into Equation (A.5) leads to the loan rate curve under the TLR.

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Table 1: Second moments when $\tau = 0.25$

TLR	Output gap	Inflation	Policy rate	Loan rate	Loan rate dispersion
0 %	7.09	34.56	51.75	49.33	0
5%	7.08	34.52	51.65	48.92	0.71
10%	7.06	34.48	51.54	48.47	1.58

Table 2: Second moments when $\tau = 0.55$

TLR	Output gap	Inflation	Policy rate	Loan rate	Loan rate dispersion
0 %	7.58	33.98	50.53	50.57	0
5%	8.60	35.89	52.53	68.10	3.80
10%	16.32	46.58	64.11	153.30	22.31

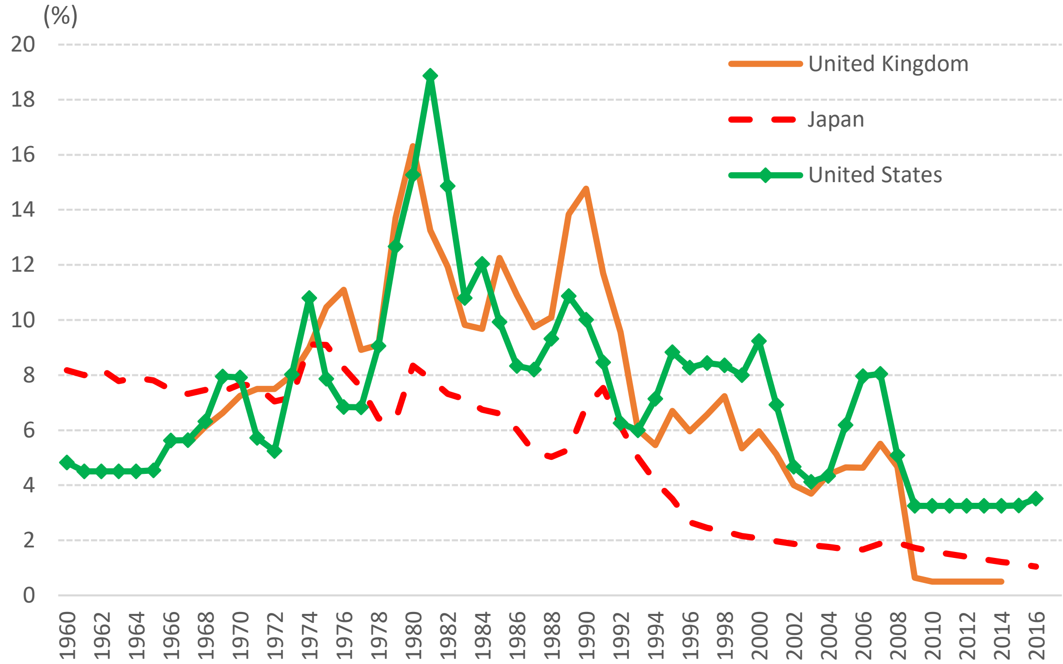
Table 3: Second moments when $\zeta = 3.6$ when $\tau = 0.5$

TLR	Output gap	Inflation	Policy rate	Loan rate	Loan rate dispersion
0 %	7.36	34.10	50.80	48.86	0
5%	7.47	34.59	51.31	52.45	0.94
10%	7.66	35.24	52.01	57.33	2.23

Table 4: Second moments when $\zeta = 10$ when $\tau = 0.5$

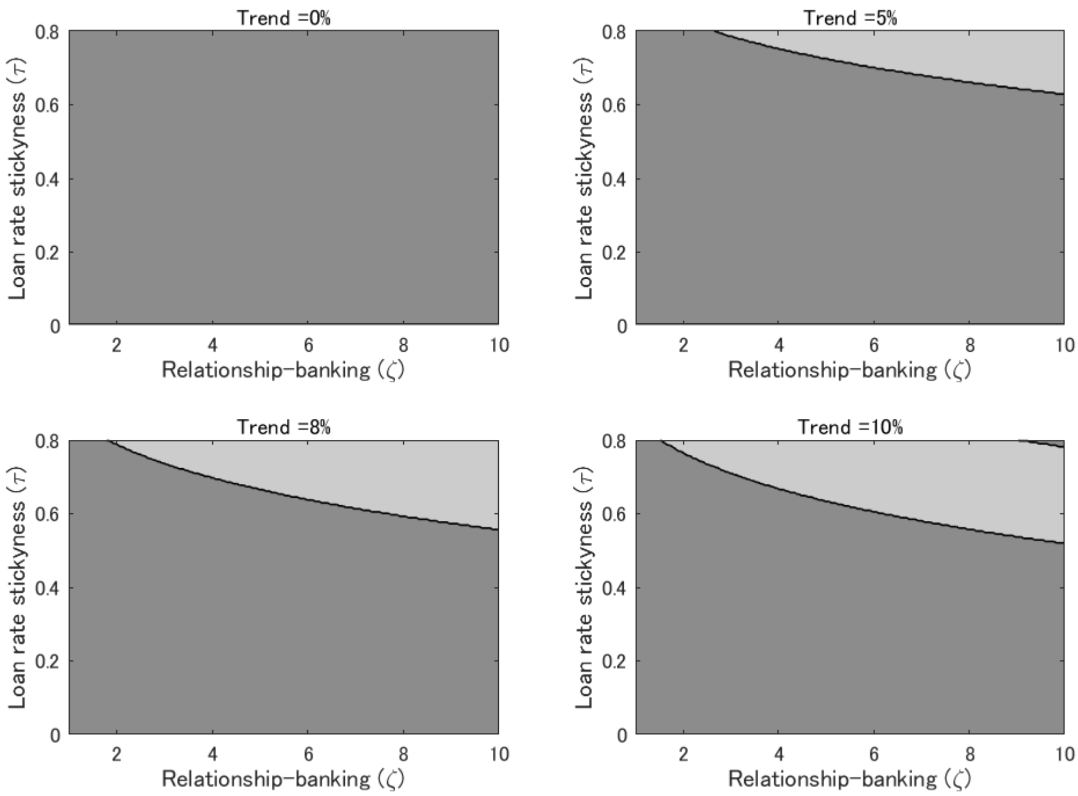
Trend loan rate	output gap	inflation	policy rate	loan rate	loan rate dispersion
0 %	7.36	34.10	50.80	48.86	0
5%	8.01	35.50	52.23	61.47	3.68
10%	12.92	42.91	60.30	121.58	19.85

Figure 1: Loan rates for the United States, the United Kingdom, and Japan (1960-2016)



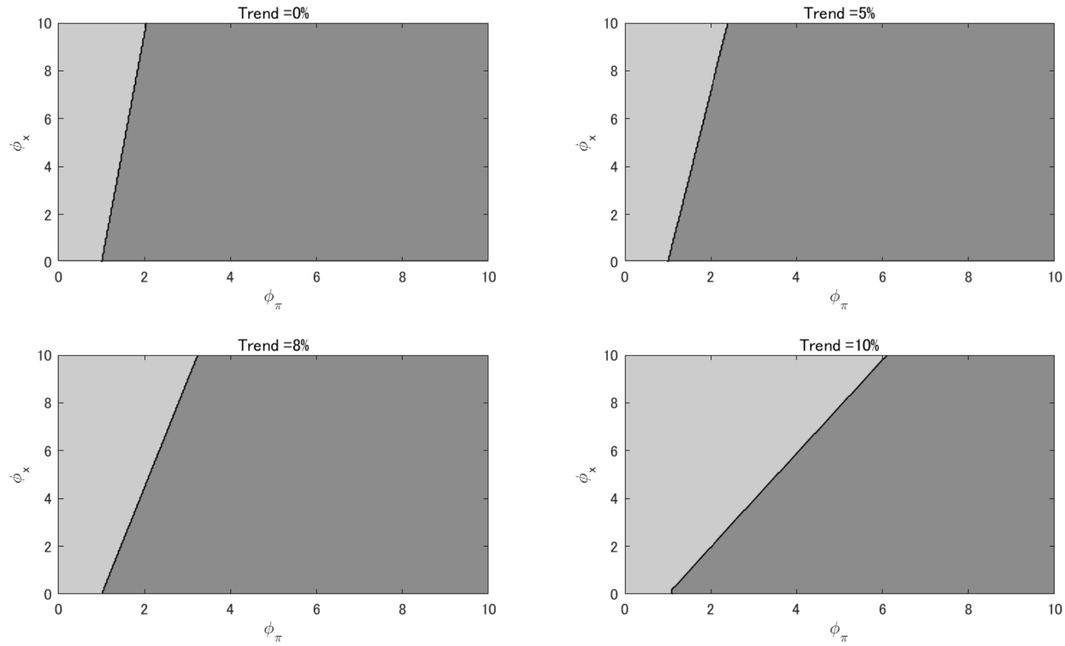
Source: World Bank database

Figure 2: Determinacy in the presence of a TLR



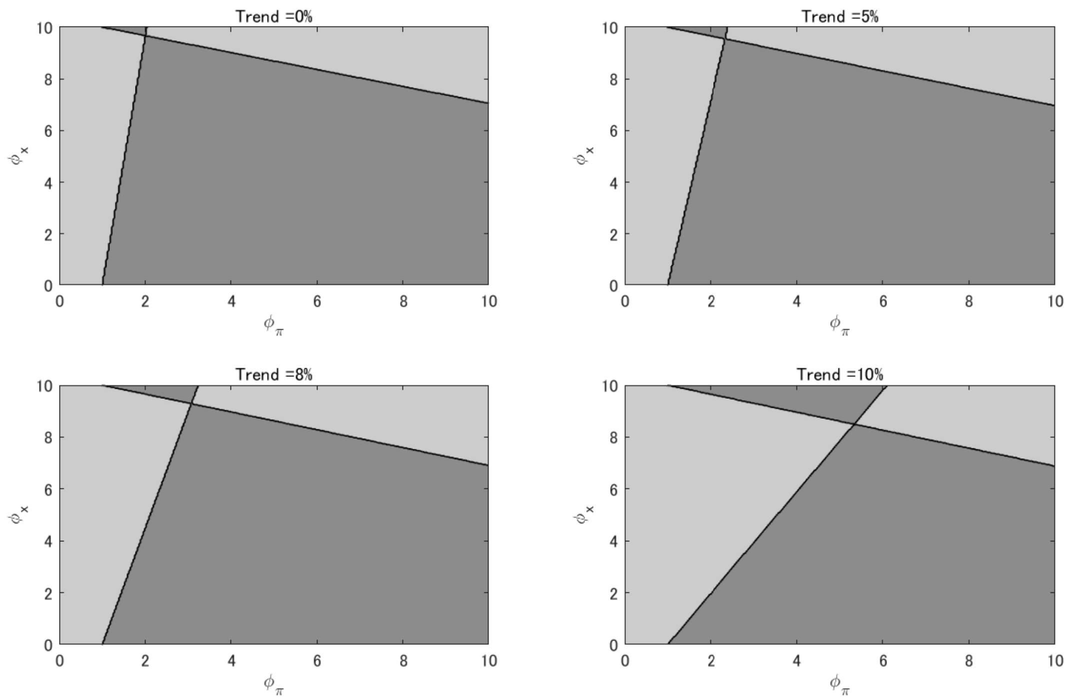
Note: Dark and light shading indicates determinate and indeterminate regions, respectively.

Figure 3: Determinacy and contemporaneous rule with a TLR



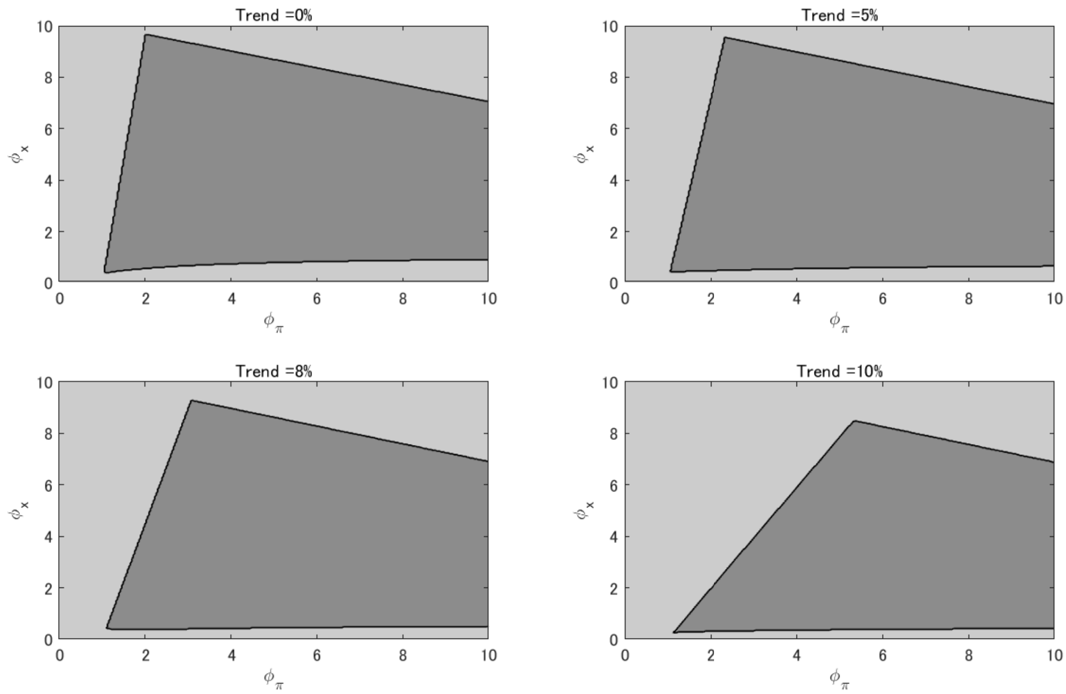
Note: Dark and light shading indicates determinate and indeterminate regions, respectively.

Figure 4: Determinacy and backward-looking rule with a TLR



Note: Dark and light shading indicates determinate and indeterminate regions, respectively.

Figure 5: Determinacy and forward-looking rule with a TLR



Note: Dark and light shading indicates determinate and indeterminate regions, respectively.

Figure 6: Impulse responses to a loan rate shock with a TLR

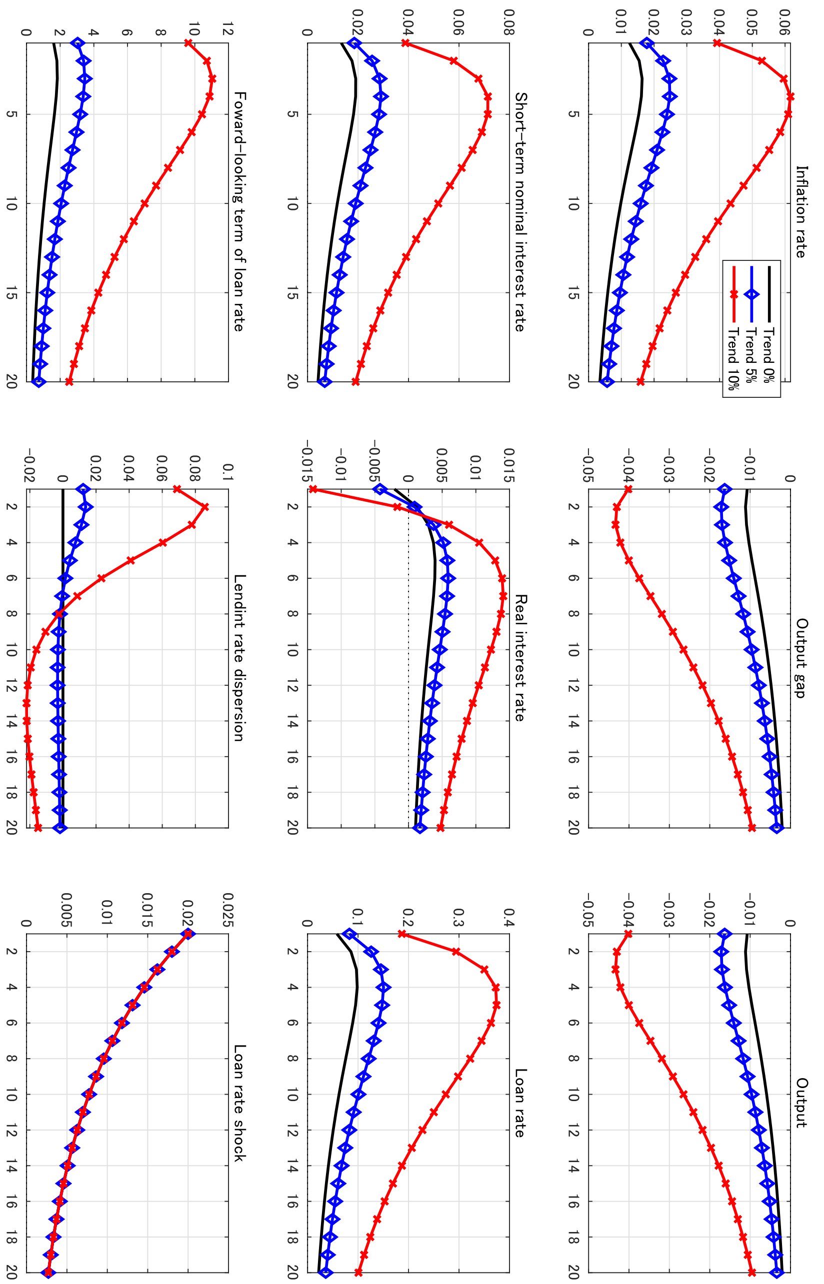


Figure 7: Impulse responses to a productivity shock with a TLR

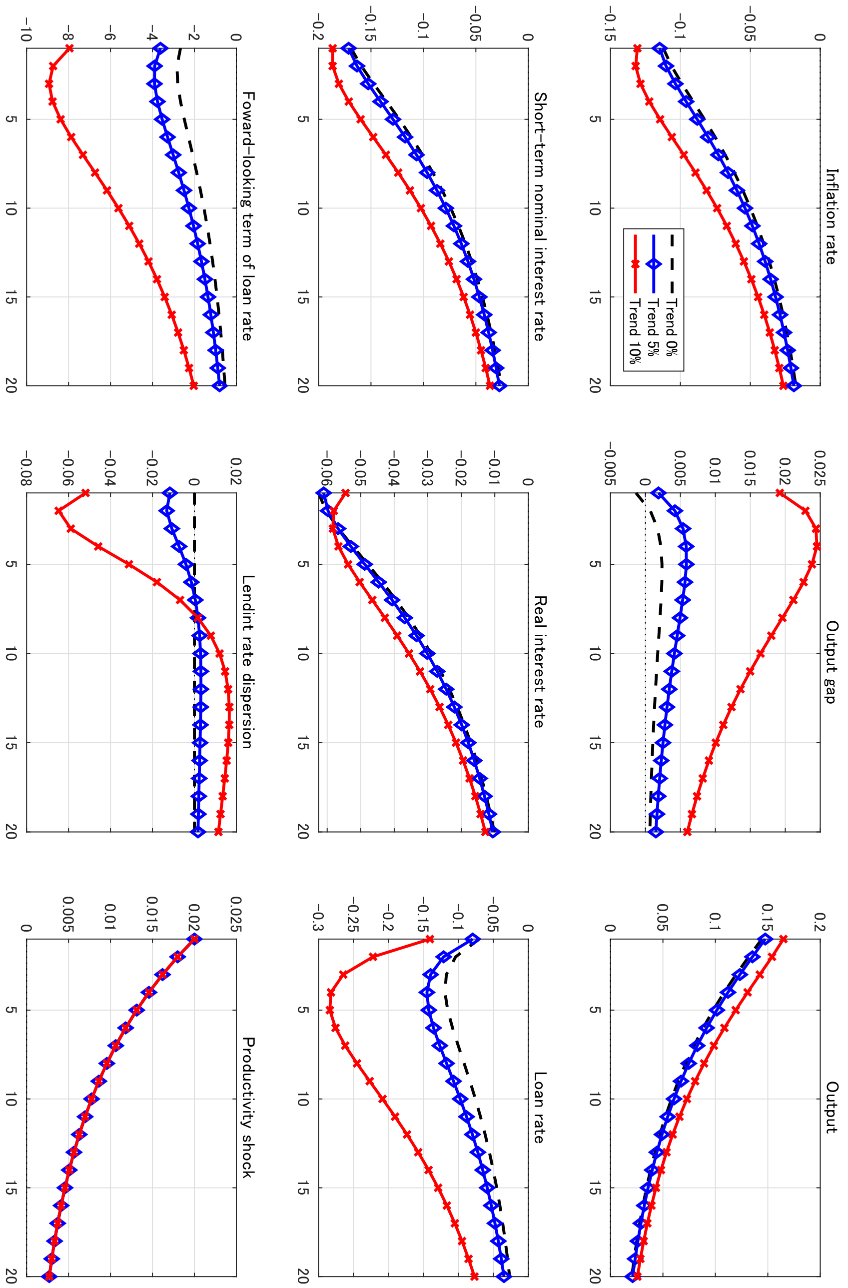


Figure 8: Impulse responses to a loan rate shock with a TLR: The role of ζ