

Optimal Macroprudential Policy for Korean Economy

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Fujimoto *et al.* (2014) set up a model with financial frictions through search and matching between firms and banks in the loan market. They also show that optimal policy criteria in the model include terms of credit variables. In this paper, we calibrate the model of Fujimoto *et al.* (2014) for South Korea and investigate the simple and optimal monetary and macroprudential policy rules that include credit variables in addition to the consumption gap and inflation rate as explanatory variables. We compare the performances of a standard Taylor rule and these optimal rules. Numerical simulations show that the simple macroprudential and monetary policy rules with credit terms can induce higher welfare than the estimated Taylor rule for the Korean economy. Simultaneously, simple macroprudential and monetary policy rules with credit terms do not always improve welfare.

Keywords: Optimal macroprudential policy, Financial market friction

JEL Classification: E44, E52, E61

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[**Seoul Journal of Economics** 2015, Vol. 28, No. 2]

I. Introduction

Given the limits of the current policy framework, which include monetary and fiscal policies in the financial crises of the last decade, policy makers have searched for new macro policy to avoid crisis and mitigate large disruption in a crisis. Macroprudential policy is a strong candidate for the new macro policy. The new policy aims to control the behavior of banks such as lending and achieves stability in the entire financial system.

In practice, some international organizations have introduced macroprudential policy, such as the Basel III framework (Basel Committee on Banking Supervision (BCBS) 2010, 2014). Under the Basel III framework, banks are required to satisfy a certain base level of capital ratio against risky assets to stabilize the volume of loan, and this base changes according to economic and financial conditions. Several countries have also introduced several types of macroprudential policies, including total credit control and capital control, as described in Lim *et al.* (2011) and Nier *et al.* (2011).

Some studies evaluate the roles of macroprudential policy using theoretical models including dynamic stochastic general equilibrium (DSGE) models. Schmitt-Grohe and Uribe (2012) develop a small open economy in which downward nominal wage rigidity pegging the nominal exchange rate induces a pecuniary externality. They show that under such an environment, the Ramsey optimal capital controls act as prudential policy in the sense that they tax capital inflows in good times and subsidize external borrowing in bad times. Eventually, this macroprudential policy reduces the average unemployment rate and average external debt, and increases welfare under reasonable parameters.

Quint and Rabanal (2011) assume a new Keynesian type DSGE model with real, nominal, and financial frictions; they study the optimal combination of monetary and macroprudential policies. They numerically show that the social welfare improves when the objective of the policy maker includes the credit term, which implies that the macroprudential policy is relevant. Suh (2012) shows that to improve welfare, macroprudential policy should respond to credit, whereas monetary policy should respond to the output gap and the inflation rate using the DSGE model with real, nominal, and financial frictions.

In this paper, we first develop a model with financial frictions by search and matching between firms and banks in the loan market as proposed

by Fujimoto *et al.* (2014). Following Fujimoto *et al.* (2014), we review the reason why simple monetary and macroprudential policy rules need to include financial variables such as volume of credit and rate of loan to obtain welfare gains. We then calibrate the model for South Korea and investigate the simple and optimal monetary and macroprudential policy rules including financial variables in addition to the consumption gap and inflation rate as explanatory variables. We compare the performances of a standard Taylor rule and these optimal rules. We also verify the sensitivity for simulation by modifying the maturity of loan contracts and the range of search parameters.

The rest of the paper is organized into sections. We formulate the model in Section II. In Section III, we show the optimal criteria for policy. In Section IV, we show numerical examples of simple and optimal monetary/macroprudential policies for the Korean economy. Section V concludes the paper.

II. Model

A. Structure

We exactly follow the model of Fujimoto *et al.* (2014). The full description of this model is shown in the Appendix. The economy is populated by four types of private agents, namely, a single representative household (consumer) and a large number of wholesale firms, banks, and retail firms.

An infinitely lived representative household derives utility only from consumption, such that

$$\max_{C,D} E_t \sum_{i=0}^{\infty} \beta^i \frac{C_{t+i}^{1-\sigma}}{1-\sigma}, \quad (1)$$

where σ is the coefficient of relative risk aversion. In period t , the household enjoys total consumption C_t and receives Π_t as a lump-sum profit from firms and banks. In addition, the household deposits D_t in a bank account is repaid at the end of period t with a nominal interest rate $R_t^D - 1$, where R_t^D is set by the central bank. The household maximizes its utility to optimally choose total consumption C_t and deposits D_t .

In any period, a wholesale firm can either be a productive firm or a credit seeker firm. To be productive, a firm must first obtain credit a from a bank to finance the cost of production. A productive wholesale

firm produces Z units of wholesale goods using inside labor with compensation a , and the labor in the productive wholesale firm consumes differentiated retail goods after production of retail goods as the consumer.

The credit market is characterized by search frictions, and a credit seeker firm must purchase retail goods κ as the consumer in each period. In period t , with probability p_t^F , a credit seeker firm is matched with a bank and engages in a credit contract. Then, the firm receives a real units of credit and becomes productive, sells the produced goods to the retail firms, and repays $R_t^L a$ to the bank, in which the loan interest rate $R_t^L - 1$ is determined in equilibrium. Finally, at the end of period t , a credit contract is exogenously terminated with probability $\rho \in (0, 1)$, in which case the firm and the bank separate and search for new matches in period $t+1$. With probability $1-\rho$, a credit contract is sustained and the firm again receives credit in period $t+1$. We denote ρ as the credit separation rate. We assume that free entry into the wholesale goods industry exists.

Banks post credit offers and search for credit seeker firms. We call these credit offers as "credit vacancies." Posting credit vacancies is costless, but the total funds available for lending is fixed at aL^* , such that the upper limit of the number of credit contracts is L^* . Therefore, the number of credit vacancies v_t using L_{t-1} is expressed as

$$v_t = L^* - (1 - \rho)L_{t-1}.$$

A credit vacancy is filled with probability q_t^B . Then, L_t is expressed as

$$L_t = (1 - \rho)L_{t-1} + q_t^B v_t.$$

Credit market tightness is defined as

$$\theta_t = \frac{u_t}{v_t}, \tag{2}$$

where u_t is the number of credit seeker firms.

Retail firms produce differentiated retail goods from the wholesale good, which are then sold to the household. Wholesale firms are in a monopolistically competitive market. One unit of wholesale goods, whose price is P_t^w , is converted into one unit of retail good j . To introduce price

stickiness, a firm is assumed to adjust its price each period with probability $1 - \omega$, as shown in the models of Calvo (1983) and Yun (1996).

The number of new credit matches in a period is given by a Cobb-Douglas matching function

$$m_t(u_t, v_t) = \chi u_t^{1-\alpha} v_t^\alpha,$$

where $\alpha \in (0, 1)$ and $\chi \in (0, 1)$ are constant parameters. A wholesale firm and a bank forming a credit match share the match surplus according to generalized Nash bargaining. Thus, R_t^L is solved as

$$\max_{R_t^L} f_t^{1-b} g_t^b,$$

where $b \in (0, 1)$ is the bargaining power for banks, f_t is the value of a productive wholesale firm, and g_t is the gain from a credit match for banks.

B. Linearized Model

We log-linearize the structural equations around the efficient steady-state equilibrium as shown in the Appendix. For general stochastic non-efficient state, the Calvo-type stickiness introduced in the retail sector results into the standard Phillips curve with a cost-push shock $\hat{\varepsilon}_t$,

$$\pi_t = \beta E_t \pi_{t+1} - \delta \left(\frac{1}{\bar{\varepsilon} - 1} \hat{\varepsilon}_t + \hat{\mu}_t \right) \tag{3}$$

where δ is a positive parameter and $\pi_t \equiv \hat{p}_t - \hat{p}_{t-1}$ is the inflation rate. The log-deviation of a variable (e.g., C_t) from its efficient steady-state value (\bar{C}) is expressed as \hat{c}_t .

The retail price markup term $\hat{\mu}_t$ in this equation can be obtained from the log-linearized version of Equation (29),

$$Z \hat{\mu}_t = -\frac{\alpha}{1-\alpha} \frac{\kappa}{\chi} \bar{\theta}^\alpha (\hat{\theta}_t - \beta \rho_u E_t \hat{\theta}_{t+1}) - \beta \delta_2 \delta (E_t \hat{c}_{t+1} - c_t), \tag{4}$$

where ρ_u and δ_2 are positive parameters.

IS relation from equation (17) is given by

$$\hat{c}_t = E_t \hat{c}_{t+1} - \frac{1}{\sigma} (\hat{r}_t^D - E_t \pi_{t+1}), \quad (5)$$

where we denote \hat{c}_t as the consumption gap.

Using the loan volume term \hat{l}_t , the credit market tightness term $\hat{\theta}_t$ is expressed as

$$\hat{\theta}_t = \frac{1}{(1-\alpha)\rho} (\hat{l}_t - \rho_u \hat{l}_{t-1}), \quad (6)$$

whereas the consumption gap \hat{c}_t is expressed as

$$\hat{c}_t = \frac{\bar{L}\delta_2}{C} (-\beta \hat{l}_t + \hat{l}_{t-1}). \quad (7)$$

Although the closed linear system is given by the five equations and the monetary policy rule is derived in the subsequent sections, we can also reveal the relation between the loan interest rate and credit volume as

$$\begin{aligned} \alpha \bar{R}^L \hat{r}_t^L &= \frac{\alpha}{1-\alpha} \frac{\kappa}{\chi} \bar{\theta}^\alpha \left[- \left(\beta \frac{1-\rho}{\rho} \frac{(\alpha - \chi \bar{\theta}^{1-\alpha})}{1-\alpha} + \beta^2 \sigma \rho_u \frac{\bar{L}}{C} \delta_2 \right) E_t \hat{l}_{t+1} \right. \\ &\quad + \left(\frac{\alpha}{(1-\alpha)\rho} + \beta \frac{(1-\rho)}{\rho} \frac{(\alpha - \chi \bar{\theta}^{1-\alpha})}{1-\alpha} \rho_u + \beta \sigma \rho_u \frac{\bar{L}}{C} \delta_2 (1+\beta) \right) \hat{l}_t \\ &\quad \left. - \left(\frac{\alpha}{1-\alpha} \frac{\rho_u}{\rho} + \beta \sigma \rho_u \frac{\bar{L}}{C} \delta_2 \right) \hat{l}_{t-1} \right]. \end{aligned} \quad (8)$$

Thus, the loan interest rate and the volume of credit have a close relationship.

III. Optimality Criteria and Optimal Policy

Using linear-quadratic (LQ) approach of Woodford (2003) and Benigno and Woodford (2012), Fujimoto *et al.* (2014) show that a second-order approximation of social welfare includes a term involving credit, in addition to terms of inflation and consumption under the model with

financial market frictions. LQ approach can analytically reveal an object of the central bank, although the effects are ignored more than the second-order. Benigno and Woodford (2012) show that the approximation error of LQ approach is sufficiently small in a fairly broad range of model specification for small shocks.

In detail, the second-order expansion of a household's utility function around the efficient steady state is given by

$$\sum_{i=0}^{\infty} \beta^i u(C_{t+i}) = -\frac{1}{2} \sum_{i=0}^{\infty} \beta^i (\lambda_{\pi} \pi_{t+i}^2 + \lambda_c \hat{c}_{t+i}^2 + \lambda_{\theta} \hat{\theta}_{t+i}^2) + t.i.p., \quad (9)$$

where $\lambda_{\pi} \equiv u_c Z \bar{L} \bar{\varepsilon} / \delta$, $\lambda_c \equiv \sigma u_c \bar{C}$, $\lambda_{\theta} \equiv u_c \kappa \bar{u} \alpha$, and $u_c \equiv u'(\bar{C})$.

Fujimoto *et al.* (2014) reveal that the optimal policy faces a trade-off among the inflation rate, consumption, and credit market tightness. The presence of credit market tightness in the approximated welfare function has a novel implication for the optimal policy. Under credit market frictions, the optimal policy should respond to the inefficient state of the credit market, although the real economy is perfectly stable with no inflation and consumption at the efficient steady state level.

Fujimoto *et al.* (2014) also show a different form of approximated welfare as

$$\begin{aligned} & \sum_{i=0}^{\infty} \beta^i u(C_{t+i}) \\ &= -\frac{1}{2} \sum_{i=0}^{\infty} \beta^i \left[\lambda_{\pi} \pi_{t+i}^2 + \lambda_c \hat{c}_{t+i}^2 + \frac{\lambda_{\theta}}{(1-\alpha)^2 \rho^2} (\hat{l}_{t+i} - \rho_u \hat{l}_{t+i-1})^2 \right] + t.i.p. \end{aligned} \quad (10)$$

Thus, the optimal policy, including macroprudential policy, requires stabilization for volume of credit. When ρ_u approaches zero, central banks need to stabilize credit variation to improve welfare.¹ By contrast, when ρ_u approaches one, central banks need to stabilize growth of credit.²

IV. Discussions

Woodford (2003) shows that under the model with frictions in the goods market, that is, price stickiness, central banks should stabilize

¹ As the separation rate ρ approaches one, ρ_u approaches zero.

² As the separation rate ρ approaches zero, ρ_u approaches one.

inflation and the consumption gaps, which roughly imply $\lambda_\theta = 0$. He justifies that the simple monetary policy rules need to include these terms to improve welfare. Thus, the policy interest rate is explained by inflation and the consumption gap in the Taylor rule.

By contrast, Fujimoto *et al.* (2014) show that under the model with financial market frictions, a second-order approximation of the social welfare includes a term involving credit, in addition to terms of inflation and consumption. This outcome implies that the simple monetary policy rules need to include a credit term in addition to terms of inflation and consumption. Thus, we suppose that the Taylor rule needs some adjustments in credit variables such as credit volume and the loan interest rate.

In reality, some central banks pay attention to financial variables to implement the monetary policy under situations in which frictions in the financial market matter. For example, Taylor (2008) points out that a spread-adjusted Taylor rule that also includes the credit spread term in the standard Taylor rule can explain the easing of monetary policy by FRB in response to subprime mortgage crisis.

Therefore, we investigate whether adjusted Taylor rules achieve higher welfare than the Taylor rule does in the model with credit market frictions.

V. Implementation of Optimal Policy for Financial Stability

A. Calibration for Korean Economy

The model period is one quarter. We use the structural parameters in Table 1 for the Korean economy. Following Choi and Hur (2014), we set the relative risk aversion σ to 0.45, the elasticity of substitution between differentiated goods $\bar{\epsilon}$ to 0.86, and the probability of price adjustment $1 - \omega$ to 0.14.

For other parameters, we assume $\beta = 0.995$ to set the steady state deposit rate to 2% per annum. We assume symmetric bargaining power ($b = 0.5$) following Den Haan, Ramey, and Watson (2003), and resort to the Hosios (1990) condition to set $\alpha = b = 0.5$.

We set $\rho = 0.025$ such that the average duration of a credit match is 10 years. We then normalize Z and L^* to 1, and choose κ , χ , and a such that the average duration of search in the credit market is one year for both wholesale firms and banks in the efficient steady state, and the annual loan rate is equal to 2.8%, which is the average real

TABLE 1
PARAMETER VALUES

Parameters	Explanation	Parameter values
β	Discount factor	0.995
σ	Relative risk aversion	0.45
$\bar{\varepsilon}$	Elasticity of substitution between differentiated goods	0.86
$1 - \omega$	Probability of price adjustment	0.14
ρ	Probability of losing a credit line	0.025
κ	Cost of searching for a credit	0.0063
χ	Coefficient for the matching function	0.25
α	Substitution between and	0.5
b	Bargaining power of banks	0.5
Z	Productivity of wholesale firms	1
a	Amount of lending for a loan contract	0.9924
L^*	Upper limit of the funds available for lending	1
ρ_l	Coefficient on the interest rate lag in the Taylor rule	0.81
ρ_c	Coefficient on the consumption gap in the Taylor rule	0.13
ρ_π	Coefficient on the inflation rate in the Taylor rule	0.5

rate of all commercial and industrial loans by commercial banks in South Korea from 2001 to 2013.

In simulation, we assume a positive 1% cost-push shock $\hat{\varepsilon}_t$ in the Phillips curve with persistence of 0.5.

B. Simulations

We check the performance of a variety of simple rules, namely, an estimated Taylor rule (TR), an estimated Taylor rule with a credit volume term (TRC), and an estimated Taylor rule with a loan interest rate term (TRL). TRC and TRL are given by

$$\begin{aligned}
 \hat{r}_t^D &= \rho_i \hat{r}_{t-1}^D + (1 - \rho_i)(\rho_c \hat{c}_{t-1} + \rho_\pi \pi_{t-1} + \rho_l \hat{l}_{t-1}), \\
 \hat{r}_t^D &= \rho_i \hat{r}_{t-1}^D + (1 - \rho_i)(\rho_c \hat{c}_{t-1} + \rho_\pi \pi_{t-1} + \rho_r \hat{r}_{t-1}^L),
 \end{aligned}
 \tag{11}$$

where ρ_i , ρ_c , ρ_π , ρ_l , and ρ_r are parameters. The introduction of credit volume and loan rate terms can be justified from Equations (10) and (8). As for TR, we use the parameters from Choi and Hur (2014), and set $\rho_i=0.81$, $\rho_c=0.13$, $\rho_\pi=0.5$, and $\rho_l=0$ in Equation (11).

In numerical simulations, we search for ρ_l and ρ_r to maximize the social welfare. The range of the policy parameters examined here is -5

TABLE 2
WELFARE ANALYSIS

Case	Value of ξ
TR	0.067
Best Case: TRC with $\rho_l=0.1$	0.038
Best Case: TRL with $\rho_r=0.6$	0.033
Worst Case: TRC with $\rho_l=0.3$	0.044
Worst Case: TRL with $\rho_r=2.4$	1.6
Best Case: TR and MRC with $\rho_l=40$	0.022
Best Case: TR and MRL with $\rho_r=40$	0.047
Worst Case: TR and MRC with $\rho_l=-10.6$	0.09
Worst Case: TR and MRL with $\rho_r=-11.4$	0.077

$\leq \rho_l \leq 5$ and $-5 \leq \rho_r \leq 5$. Table 2 shows welfare for different rules. The welfare measure, evaluated by steady-state consumption, is given by the ratio ξ of a loss of alternative rule to that of the optimal monetary policy, as shown in Ravenna and Walsh (2011).

$$\frac{U[(1 + \xi)\bar{C}]}{1 - \beta} + L^{spr} + t.i.p. = \frac{U[\bar{C}]}{1 - \beta} + L^{opt} + t.i.p.,$$

where L^{opt} is the welfare loss under the optimal monetary policy given by the first term on the right-hand side (RHS) of Equation (9) and L^{spr} is the welfare loss under alternative simple policy rules. As ξ becomes larger, the alternative simple rule results in larger welfare loss in terms of steady-state consumption.

The findings in the simulations are as follows. First, TRC and TRL perform better than TR under appropriate choices of parameters. In our exercise, TRC (TRL) shows the best performance, with $\xi=0.038$ ($\xi=0.033$), when ρ_l (ρ_r) is 0.1 (0.6) as shown in the first (second) row, whereas $\xi=0.067$ for TR. These results are consistent with the theoretical investigation in the previous sections. In the Korean economy, the monetary policy focuses on the condition that credit volume and loan interest rate can perform well. Second, the best parameters of ρ_l and ρ_r are both positive. By increasing the policy rate, the loan interest rate increases. Thus, the future volume of credit decreases, which eliminates inefficient credit boom and achieving welfare improvement. Third, TRL shows better performance than TRC. Thus, for the Korean economy, adjustment in the loan interest rate on TR improves welfare more than that by credit volume. Fourth, TRC and TRL perform worse than TR when

the parameters are not set appropriately, as shown in the third (forth) row. TRC (TRL) shows the worst performance as $\xi=0.44$ ($\xi=1.6$) when ρ_l (ρ_r) is 0.3 (2.4).

Inflation variability, consumption variability, and credit variables in the best TRC and TRL reported above have relative importance. The values of $\rho_c=0.13$ and $\rho_\pi=0.5$, are obtained from Choi and Hur (2014), which implies that the central bank responds more strongly to inflation than to consumption (or equivalently, output). In the case of TRC, $\rho_l=0.1$ maximizes welfare, which indicates that the central bank should respond as strongly to credit volume as to consumption. As for TRL, the best value of ρ_r is 0.6, requiring a stronger response to the loan interest rate than to inflation.

We also check the performance of the simple macroprudential policy rule combined with TR. Here, we assume that the macroprudential authority aims to stabilize only the loan volume, such that the credit variation is the unique explanatory variable. This situation follows the conventional view of macroprudential policy. For example, the new Basel regulation imposes capital requirement on banks to primarily control the loan volume as in BCBS (2010, 2014). Moreover, Drehmann, Borio, and Tsatsaronis (2012) show that the variation of credit can be a good indicator to implement a macroprudential policy. We also consider the case in which the credit variation is replaced by the loan interest rate. More precisely, we assume that the macroprudential authority controls the bank's bargaining power b_t in the Nash bargaining problem in response to the variation in credit or loan interest rate. In reality, the macroprudential authority controls the degree of banks' competition in the credit market by changing the financial regulations. In this case, the markup Equation (4) changes to

$$\begin{aligned}
 Z\hat{\mu}_t = & -\frac{\alpha}{1-\alpha} \frac{\kappa}{\chi} \bar{\theta}^\alpha (\hat{\theta}_t - \beta\rho_u E_t \hat{\theta}_{t+1}) \\
 & -\beta\delta_2\sigma(E_t \hat{c}_{t+1} - \hat{c}_t) - \frac{b}{(1-b)^2} \frac{\kappa}{\chi} \bar{\theta}^\alpha (\hat{b}_t - \beta\rho_u E_t \hat{b}_{t+1}).
 \end{aligned}
 \tag{12}$$

The simple macroprudential policy rules are given by

$$\hat{b}_t = \rho_l \hat{l}_{t-1},
 \tag{13}$$

$$\hat{b}_t = \rho_r \hat{r}_{t-1}^L. \quad (14)$$

We call these simple macroprudential rules as the macroprudential rule with credit variation (MRC) and the macroprudential rule with loan rate variation (MRL). By contrast, the central bank is only responsible for the stability of inflation and the consumption gap. Thus, we assume TR for the monetary policy.

The range of the policy parameters examined is $-40 \leq \rho_l \leq 40$ and $-40 \leq \rho_r \leq 40$. The result is reported in Table 2. MRC (MRL) performs better than TR, with $\xi = 0.022$ ($\xi = 0.047$) when $\rho_l = 40$ ($\rho_r = 40$), as shown in the fifth (sixth) row. Thus, the joint management of the macroprudential policy and monetary policy can achieve higher welfare than monetary policy alone. Moreover, MRC shows better performance than MRL. This result is different from that of simple monetary policy rule with credit terms.

However, under inappropriate parameters, MRC (MRL) performs worse than TR, with $\xi = 0.09$ ($\xi = 0.071$) when $\rho_l = -10.6$ ($\rho_r = -11.4$), as shown in the seventh (eighth) row.

C. Change for Average Duration of a Credit Match

For sensitivity analysis, we change the average duration of a credit match to five years. Thus, we set $\rho = 0.05$.³ Table 3 shows welfare for different rules.

First, welfare improves and deteriorates with TRC, TRL, MRC, and MRL in some cases. Thus, parameter settings are important to achieve welfare improvements. Second, TRL shows better performance than TRC. Third, MRC performs better than MRL. These results have some robustness.

D. Change in Range of Search for Optimal Parameters

We now expand the range of search for optimal parameters because the optimal parameters for MRC and MRL are at the upper bound of the range. The range of the policy parameters examined has expanded to $-100 \leq \rho_l \leq 100$ and $-100 \leq \rho_r \leq 100$. The result is reported in Table 4. MRC (MRL) shows better performance than TR, with $\xi = -0.015$ ($\xi = 0.0092$) when $\rho_l = 100$ ($\rho_r = 100$). Other cases from Table 3 do not change.

Interestingly, MRC with $\rho_l = 100$, welfare is higher than in the optimal

³In this case, α is 0.9918 and κ is 0.0059 with other parameters unchanged.

TABLE 3
WELFARE ANALYSIS: SENSITIVITY FOR ρ

Case	Value of ξ
TR	0.055
Best Case: TRC with $\rho_l=0.1$	0.042
Best Case: TRL with $\rho_r=0.9$	0.029
Worst Case: TRC with $\rho_l=-0.7$	0.067
Worst Case: TRL with $\rho_r=2.5$	0.56
Best Case: TR and MRC with $\rho_l=40$	0.0036
Best Case: TR and MRL with $\rho_r=40$	0.042
Worst Case: TR and MRC with $\rho_l=-5.6$	0.068
Worst Case: TR and MRL with $\rho_r=-12.3$	0.057

TABLE 4
WELFARE ANALYSIS: SENSITIVITY FOR THE RANGE OF SEARCH FOR
PARAMETERS

Case	Value of ξ
TR	0.055
Best Case: TR and MRC with $\rho_l=100$	-0.014
Best Case: TR and MRL with $\rho_r=100$	0.0092

monetary policy because we assume the cost-push shock and macroprudential policy is set in the markup equation. Thus, the simple macroprudential policy rule can provide a large gain apart from the monetary policy, although such an outcome is sensitive to the shock and the macroprudential measure.

VI. Conclusion

We show that the simple macroprudential and monetary policy rules with credit terms can induce higher welfare than the estimated Taylor rule under the parameters calibrated for the Korean economy. Thus, an introduction of simple macroprudential policy in addition to the monetary policy can improve welfare in the Korean economy.

The following points could be of interest for future research. By extending the model into an open economy, utilizing optimal capital control as the optimal macroprudential policy becomes possible. In this case, it would be interesting to investigate the dynamics of exchange rate under capital control.

Appendix

A. Model

We exactly follow the model of Fujimoto *et al.* (2014). The model economy has four types of private agents, namely, a single representative household (consumer) and a large number of wholesale firms, banks, and retail firms. We explain the problems these agents encounter. We then describe the credit market, which is characterized by search and matching frictions, as well as the goods market.

A.1 Household

An infinitely lived representative household derives utility only from consumption. In period t , the household enjoys total consumption C_t and receives Π_t as a lump-sum profit from firms and banks. In addition, the household deposits D_t in a bank account to be repaid at the end of period t with a nominal interest rate $R_t^D - 1$, where R_t^D is set by the central bank. Both Π_t and D_t are in real terms (*i.e.*, in units of total consumption), and the price of C_t is P_t .

The household's problem is

$$\max_{C,D} E_t \sum_{i=0}^{\infty} \beta^i u(C_{t+i}), \quad (15)$$

subject to the budget constraint

$$C_t = \Pi_t + \frac{R_{t-1}^D D_{t-1} - D_t}{P_t}. \quad (16)$$

The household's period utility function is

$$u(C_t) \equiv \frac{C_t^{1-\sigma}}{1-\sigma},$$

where σ is the coefficient of relative risk aversion.

This optimization problem leads to

$$\lambda_t = C_t^{-\sigma},$$

$$1 = \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \frac{P_t}{P_{t+1}} R_t^D \right], \tag{17}$$

where λ_t is the Lagrange multiplier on the budget constraint (16).

Total consumption C_t is an aggregate of differentiated retail goods, labeled as $j \in [0, 1]$. Consumption of each good $c_t(j)$ is related to C_t by

$$C_t \equiv \left[\int_0^1 c_t(j)^{\frac{\varepsilon_t-1}{\varepsilon_t}} dj \right]^{\frac{\varepsilon_t}{\varepsilon_t-1}},$$

where $\varepsilon_t \in (1, \infty)$ is an exogenous stochastic variable related to the elasticity of substitution. The household chooses each $c_t(j)$ to minimize the cost $\int_0^1 p_t(j)c_t(j) dj$, given the level of C_t and the price of each good, $p_t(j)$. This minimization yields

$$c_t(j) = \left[\frac{p_t(j)}{P_t} \right]^{-\varepsilon_t} C_t,$$

where

$$P_t \equiv \left[\int_0^1 p_t(j)^{1-\varepsilon_t} dj \right]^{\frac{1}{1-\varepsilon_t}}. \tag{18}$$

A.2 Wholesale Firms

In any period, a wholesale firm can be either a productive or a credit seeker firm. To be productive, a firm must first obtain credit from a bank to finance the cost of production. A productive wholesale firm produces Z units of wholesale goods using inside labor with compensation a , and the labor in the productive wholesale firm consumes differentiated retail goods $a_t(j)$ after production of retail goods, where $a_t(j)$ must satisfy

$$\left[\int_0^1 a_t(j)^{\frac{\varepsilon_t-1}{\varepsilon_t}} dj \right]^{\frac{\varepsilon_t}{\varepsilon_t-1}} \geq a.$$

The cost minimization for $a_t(j)$ is parallel to of $c_t(j)$ in the household's problem.

The credit market is characterized by search frictions, credit seeker firm must purchase retail goods $\kappa_t(j)$ with the same cost minimization in each period to satisfy

$$\left[\int_0^1 \kappa_t(j)^{\frac{\varepsilon_t-1}{\varepsilon_t}} dj \right]^{\frac{\varepsilon_t}{\varepsilon_t-1}} \geq \kappa,$$

where $\kappa > 0$ is the flow cost of searching for credit. Unlike the cost of production, firms finance the cost of searching for credit by issuing stocks to the household for simplicity.⁴

In period t , with probability p_t^F , a credit seeker firm is matched with a bank and engages in a credit contract. Then, the firm receives a real units of credit and becomes productive, sells the produced goods to the retail firms, and repays R_t^L a to the bank, in which the loan interest rate $R_t^L - 1$ is determined in equilibrium. Finally, at the end of period t , a credit contract is exogenously terminated with probability $\rho \in (0, 1)$, in which case the firm and the bank separate and search for new matches in period $t+1$. With probability $1 - \rho$, a credit contract is sustained and the firm again receives credit in period $t+1$. We denote ρ as the credit separation rate.

We assume free entry into the wholesale goods industry exists. Therefore, in equilibrium, the value of a credit seeker firm is zero; thus, the value of a productive wholesale firm is expressed as⁵

$$f_t = \frac{Z}{\mu_t} - R_t^L a + \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} (1 - \rho) f_{t+1} \right], \quad (19)$$

where

⁴ Even when wholesale firms and banks exchange their roles in the loan market, where wholesales firms post credit vacancies and banks pay for the cost of searching in the loan market, a form of a second-order approximation to the welfare function in the following sections does not change as shown in the previous version of the paper of Munakata, Nakamura, and Teranishi (2013).

⁵ The total value of wholesale firms can be positive because of the value of a productive wholesale, justifying stockholding of the household for wholesale firms.

$$\mu_t \equiv \frac{P_t}{P_t^w}$$

is the price markup by retail firms and P_t^w is the price of a wholesale good. The first two terms in RHS of (19) show the net current profit from production, whereas the third term is the discounted present value of the future profit. Moreover, the cost of searching for credit must equal that of the expected revenue:

$$\kappa = P_t^F f_t. \tag{20}$$

Given these assumptions, the demand for retail good j and the total demand are

$$y_t^d(j) \equiv c_t(j) + a_t(j)L_t + \kappa_t(j)u_t,$$

and

$$Y_t^d \equiv C_t + aL_t + \kappa u_t,$$

respectively, where L_t is the number of the productive wholesale firms and u_t is the number of the credit seeker firms. y_t^d is related to Y_t^d by the following equation:

$$y_t^d(j) = \left[\frac{P_t(j)}{P_t} \right]^{-\varepsilon_t} Y_t^d. \tag{21}$$

A.3 Banks

Banks post credit offers and search for credit seeker firms. These post credit offers are denoted as “credit vacancies.” Posting credit vacancies is costless, but the total funds available for lending is fixed at aL^* ,⁶ such that the upper limit of the number of credit contracts is L^* .⁷ Therefore, the number of credit vacancies v_t using L_{t-1} is expressed as

$$v_t = L^* - (1 - \rho)L_{t-1}. \tag{22}$$

⁶ For simplicity, we assume that aL^* is less than the amount of deposit.

⁷ In reality, the limit of credit is determined by regulations, such as the leverage ratio regulation.

A credit vacancy is filled with probability q_t^B . Then, L_t is expressed as

$$L_t = (1 - \rho)L_{t-1} + q_t^B v_t.$$

In these settings, the value of a credit match for banks is

$$g_t^1 = a(R_t^L - 1) + \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \{ (1 - \rho)g_{t+1}^1 + \rho[q_{t+1}^B g_{t+1}^1 + (1 - q_{t+1}^B)g_{t+1}^0] \} \right).$$

The first term on RHS shows the current profit from lending, whereas the second term represents the discounted present value of the future profit. By contrast, the value of a credit vacancy for banks is

$$g_t^0 = \beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} [q_{t+1}^B g_{t+1}^1 + (1 - q_{t+1}^B)g_{t+1}^0] \right\}.$$

Given that a credit vacancy does not yield any current profit, it only has the discounted future values. These two equations imply that the gain from a credit match for banks is

$$g_t \equiv g_t^1 - g_t^0 = a(R_t^L - 1) + \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} (1 - \rho)(1 - q_{t+1}^B)g_{t+1}^1 \right]. \quad (23)$$

A.4 Retail Firms

Retail firms produce differentiated retail goods from wholesale good, which are then sold to the household. Wholesale firms are in a monopolistically competitive market. One unit of wholesale goods, whose price is P_t^w , is converted into one unit of retail good j . To introduce price stickiness, a firm is assumed as capable of adjusting its price each period with probability $1 - \omega$ as shown in the models of Calvo (1983) and Yun (1996). Given that the demand for good j is given by Equation (21), the profit maximization problem of a retail firm that has the opportunity to adjust its price P_t^* becomes

$$\max_{P_t^*} E_t \sum_{i=0}^{\infty} (\omega\beta)^i \left[\left(\frac{\lambda_{t+i}}{\lambda_t} \right) \left(\frac{(1 + \tau)P_t^* - P_{t+i}^w}{P_{t+i}} \right) \left(\frac{P_t^*}{P_{t+i}} \right)^{-\epsilon_{t+i}} Y_{t+i}^d \right].$$

We assume that the subsidy for firms τ is set to ensure that the price flexibility is achieved at the efficient steady-state equilibrium discussed below. The average price level P_t is given by

$$P_t^{1-\varepsilon_t} = (1 - \omega)(P_t^*)^{1-\varepsilon_t} + \omega P_{t-1}^{1-\varepsilon_t}.$$

A.5 Credit Market

The number of new credit matches in a period is given by a Cobb-Douglas matching function

$$m_t(u_t, v_t) = \chi u_t^{1-\alpha} v_t^\alpha,$$

where $\alpha \in (0, 1)$ and $\chi \in (0, 1)$ are constant parameters. Credit market tightness is defined as⁸

$$\theta_t = \frac{u_t}{v_t}, \tag{24}$$

we obtain

$$p_t^F = \chi \theta_t^{-\alpha}, \tag{25}$$

$$q_t^B = \chi \theta_t^{-\alpha}, \tag{26}$$

$$L_t = (1 - \rho)L_{t-1} + \chi \theta_t^{-\alpha} v_t. \tag{27}$$

A wholesale firm and a bank forming a credit match share the match surplus according to generalized Nash bargaining. Thus, R_t^L solves

$$\max_{R_t^L} f_t^{1-b} g_t^b,$$

where $b \in (0, 1)$ is the bargaining power for banks. By taking the first-order condition with respect to R_t^L ,

⁸In our environment, u_t and v_t correspond to the demand and supply of credit, respectively. Thus, market tightness is defined as u_t/v_t , rather than its inverse.

$$bf_t = (1-b)g_t. \quad (28)$$

For convenience, we simplify Equations (19) and (23) using Equations (20), (25), (26), and (28) to eliminate p_t^F , q_t^B , f_t , and g_t , to yield

$$\frac{\kappa}{\chi} \theta_t^\alpha = \frac{Z}{\mu_t} - aR_t^L + \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} (1-\rho) \frac{\kappa}{\chi} \theta_{t+1}^\alpha \right]$$

and

$$\frac{b}{1-b} \frac{\kappa}{\chi} \theta_t^\alpha = (R_t^L - 1)a + \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} (1-\rho)(1-\chi\theta_{t+1}^{1-\alpha}) \frac{b}{1-b} \frac{\kappa}{\chi} \theta_{t+1}^\alpha \right].$$

if we further eliminate R_t^L from these equations, we obtain the following condition that relates to markup μ_t with credit market tightness θ_t :

$$\frac{Z}{\mu_t} = a + \frac{1}{1-b} \frac{\kappa}{\chi} \theta_t^\alpha - \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} (1-\rho) \frac{1}{1-b} \left(\frac{\kappa}{\chi} \theta_{t+1}^\alpha - b\kappa\theta_{t+1} \right) \right]. \quad (29)$$

Thus, the credit market has an effect on the real economy, that is, price setting behavior, through the cost channel.

A.6 Goods Market Clearing Condition

Given that one unit of wholesale goods is needed as an input to produce one unit of each retail good j , the market clearing condition for wholesale goods is

$$ZL_t + \int_0^1 y_t^d(j) dj.$$

Together with the demand equation for retail goods (21), the following goods market clearing condition is obtained:

$$\frac{ZL_t}{Q_t} = C_t + aL_t + \kappa u_t, \quad (30)$$

where

$$Q_t \equiv \int_0^1 \left[\frac{P_t(j)}{P_t} \right]^{-\varepsilon_t} dj \tag{31}$$

represents the dispersion of prices of retail goods due to price stickiness for retail firms.

A.7 Efficient Steady-State Equilibrium

The efficient steady-state equilibrium is defined as a steady-state equilibrium of the deterministic model that exhibits no credit matching inefficiency or price markup. Such an equilibrium can be achieved only when: (1) the Hosios condition for credit market holds, that is, the bargaining power of banks (b) equals the elasticity of the matching function with respect to credit vacancies (α) and (2) the subsidy for retail firms τ is chosen to ensure $\bar{\mu} = \bar{\varepsilon} / (\bar{\varepsilon} - 1)(1 + \tau) = 1$.

The allocation in the efficient steady-state equilibrium can be obtained by solving the optimization problem of a benevolent social planner,

$$\begin{aligned} \max_{C, L, v, \theta} E_t \sum_{i=0}^{\infty} \beta^i & \left\{ \frac{C_{t+i}^{1-\rho}}{1-\sigma} + \phi_{t+i} [ZL_{t+i} - aL_{t+i} - \kappa\theta_{t+i}v_{t+i} - C_{t+i}] \right. \\ & \left. + \psi_{t+i} [(1-\rho)L_{t+i-1} + \chi\theta_{t+i}^{1-\alpha}v_{t+i} - L_{t+i}] + s_{t+i} [v_{t+i} - L^* + (1-\rho)L_{t+i-1}] \right\}, \end{aligned}$$

where ϕ_t , ψ_t , and s_t are Lagrange multipliers for the constraints. The solution to this problem yields the condition that characterizes the efficient steady-state equilibrium:

$$Z - a - \frac{1}{1-\alpha} \frac{\kappa}{\chi} \bar{\theta}^\alpha = -\beta(1-\rho) \frac{1}{1-\alpha} \frac{\kappa}{\chi} \bar{\theta}^\alpha (1 - \alpha\chi\bar{\theta}^{1-\alpha}). \tag{32}$$

The bar above each variable (e.g., $\bar{\theta}$) implies the efficient steady-state value of the variable (θ).

Let

$$\delta_1 \equiv Z - a - \frac{1}{1-\alpha} \frac{\kappa}{\chi} \bar{\theta}^\alpha$$

and

$$\delta_2 \equiv (1 - \rho) \frac{1}{1 - \alpha} \frac{\kappa}{\chi} \bar{\theta}^\alpha (1 - \alpha \chi \bar{\theta}^{1-\alpha})$$

to simplify the expression above as

$$\delta_1 = -\beta \delta_2. \quad (33)$$

Given $q^B(\bar{\theta}) = \chi \bar{\theta}^{1-\alpha} \leq 1$, then $\delta_2 \geq 0$, and thus $\delta_1 \leq 0$.

(Received 2 July 2014; Revised 2 April 2015; Accepted 8 April 2015)

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