The Cost Channel Effect of Monetary Policy in Korea

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June 16, 2008

Abstract

Contractionary monetary policy reduces the price level in the long run, but it is frequently observed that a positive interest rate shock raises the price level at a short horizon. Impulse response analysis and estimation of an interest rate augmented Phillips curve in Korea indicate the existence of a cost channel effect of monetary policy before the currency crisis period. Based upon these empirical results, this paper develops a dynamic stochastic general equilibrium model in order to explain the price responses in Korea. The cost channel of monetary policy transmission is a key feature in the model. Moreover, in order to examine the role of the banking sector in the monetary policy transmission given cost channel, an explicit loan production function in the banking sector is introduced. I find from policy simulation that the cost channel effect of monetary policy has fallen dramatically since the currency crisis in 1997. The model suggests that this result comes mainly from the facts that it takes longer for firms to adjust their output prices, and that the capital adjustment cost has declined since the currency crisis. I also find that, despite the existence of the cost channel, when the banking sector supplies loans efficiently, monetary policy has an effect on the economy mainly through the changing of aggregate demand. This implies that, given the existence of the cost channel, the central bank can reduce undesirable output price movements by enhancing the efficiency of the banking sector.

Keywords : Price puzzle, cost channel, loan premium, DSGE, monetary policy, loan production function

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[†]I thank the committee (Kyuil Chung, ByoungHark Yoo and Bae-Geun Kim) and seminar participants at the Bank of Korea for their helpful comments.

JEL Specification : E41, E52.

Contents

1 Introduction

A contractionary monetary policy shock reduces the price level in the long run, but it is frequently observed that a positive interest rate shock raises the price level at a short horizon. The standard new Keynesian model fails to explain this puzzling price response. That is, the standard new Keynesian model suggests that an increased interest rate reduces demand for consumption and investment, and that aggregate demand and the price level should therefore fall.

One group of studies, such as Sims (1992) among many others, argues that the price puzzle comes from the omission of important variable(s) in the state vector of the vector autoregression analysis. One such variable is future inflationary pressure as measured by the commodity price index. Since policymakers take a future inflationary pressure into account when they formulate monetary policy, omission of such variables from empirical models could cause the price level to move in the wrong direction. Castelnuovo and Srico (2005) argue that the price puzzle in the U.S. data is observed mostly in the pre-Volker period. Hanson (2000), however, shows that the price puzzle cannot be resolved by including various types of variables to account for future inflationary pressure.

Another group of studies shows that the price response in question is not a puzzling result. When we take into account firms' cost side effects, such models can explain the positive short horizon response of output prices to a positive interest rate shock. Since the higher interest rate means higher financing costs to firms using the loan market to finance their factor costs, the increased interest rate reduces output by leading to less factor use. Aggregate output falls, and if the reduction in aggregate demand is smaller than that in aggregate supply, the price level could rise in response to the positive interest rate shock.

Barth and Ramey (2000) show the existence of a cost channel of monetary policy

transmission using U.S. industrial level data. Gaiotti and Secchi (2004) use Italian firm level data to show the cost channel in Italy. Ravenna and Walsh (2006) test the existence of cost channel by estimating a modified Phillips curve in which the nominal interest rate is added, and conclude that the nominal interest rate has a positive relationship with inflation. Kaufmann and Scharler (2000) find the cost channel in the Euro area, and Chowdhury et.al. (2006) show that the cost channel works in G7 countries.

In this paper, empirical findings with Korean data using vector autoregression analysis and estimation of an interest rate augmented Phillips curve turn out to be not different from the results of the second group detailed above. Based upon these findings, this study aims at explaining the price responses to monetary policy shock at long and short horizons in Korea, using a dynamic stochastic general equilibrium (DSGE) model. I will show how the cost channel effect has varied across time, and derive the policy implications.

This paper also addresses the role of the banking sector, which transmits the monetary policy effect to the private sector. The empirical results show the negative response of the loan premium, which is an extra cost to borrowers over the risk free rate or the deposit rate, to a contractionary monetary policy shock. This implies that the banking sector attenuates the effect of policy on the economy, as the negative loan premium response to contractionary monetary policy shock reduces firms' financing costs, and hence the reduction in output supply is less severe than in the case of a positive loan premium response. In this vein, firms in my model are assumed to finance labor costs in the imperfect loan market which requires an additional cost over the risk free rate or the deposit rate. In order to account for the existence of a loan premium, the banking sector is assumed to produce loan supply with collateral service and monitoring costs. The marginal cost of producing loan supply is derived to be the loan premium over the risk free rate. I find from policy simulations that,

given the cost channel, the central bank's policy has an effect on the economy mainly through changing aggregate demand when the banking sector supplies loan efficiently by reducing loan premiums.

The paper is organized as follows. In section 2, the price response to a monetary policy shock is discussed. This section also tests the existence of a cost channel effect in the Korean economy by estimating a modified Phillips curve. The results for two different sample periods are compared, in order to see how the cost channel effect has changed across time. Section 3 builds a DSGE model in which the cost channel and the explicit loan production fuction in the banking sector are included. In this section, I perform some policy simulations with the two sample periods and comparing the results to see again how the cost channel has changed across time. And section 4 then concludes.

2 Empirical Test of the Cost Channel of Monetary Policy

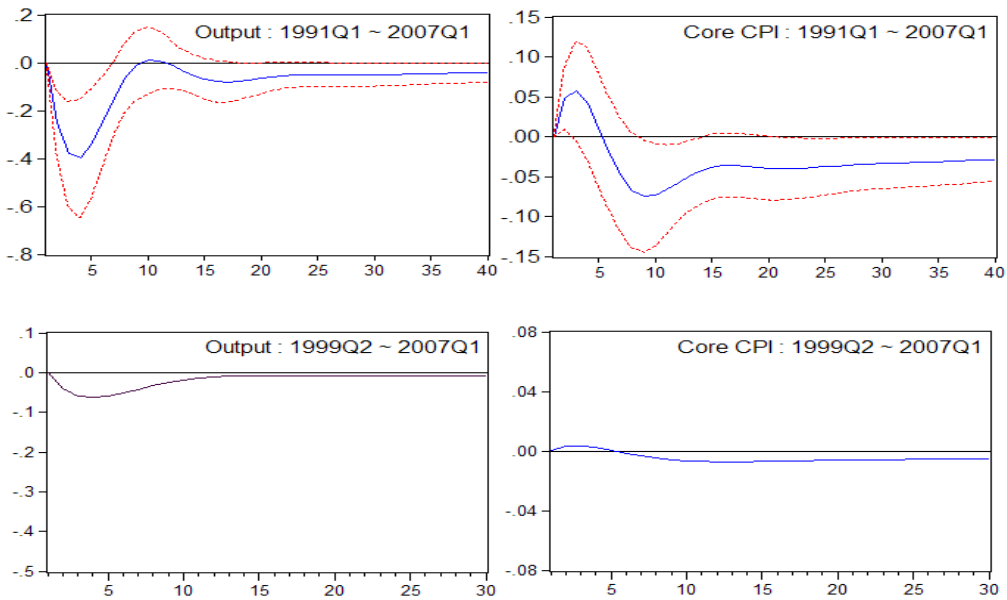
2.1 Impulse Responses

In this section, I investigate the impulse response functions (IRFs) of macrovariables to a contractionary monetary policy shock, using Korean data. The state vector consists of output (y_t) measured by real GDP, core CPI (p_t), and the call rate (R_t). The order of the state variables is given by $X_t = [y_t, p_t, R_t]$. Using Cholesky decomposition, structural shocks are identified. A lag of vector autoregression (VAR) is set by $k = 1$ using Akaike information criterion[1]. The VAR formula is given by

$$X_t = \rho(k)X_{t-1} + e_t$$

[1]Other information criteria result in the same lag length.

Figure 1: Impulse responses to an interest rate shock (%)



The solid lines represent the impulse responses to a one-standard error shock, and the dotted lines represent 95% confidence intervals. The confidence intervals for the post currency crisis period are omitted, because the impulse responses are not statistically significant.

where e_t is a vector of reduced form shocks. I use 1991:Q1 to 2007:Q1 data, and add a dummy variable (1997:Q4 to 1999:Q4) reduce the possible distortion of estimation results from inclusion of the currency crisis period.

The solid lines of Figure 1 represent the IRFs of the state variables, and the dotted lines represent 95% confidence intervals. The top row in the figure represents the IRFs of output and price level to a one-standard deviation positive interest rate shock. The positive interest rate shock reduces output for three quarters. We can clearly see the price puzzle: the price level rises for the first two quarters.

In order to see whether the macrovariables show the same responses to a policy shock even after the Bank of Korea begins using the call rate as a policy instrument under its inflation targeting regime, I perform the same analysis with the data after 1999:Q2 (the post currency crisis period). The second row in Figure 1 shows the

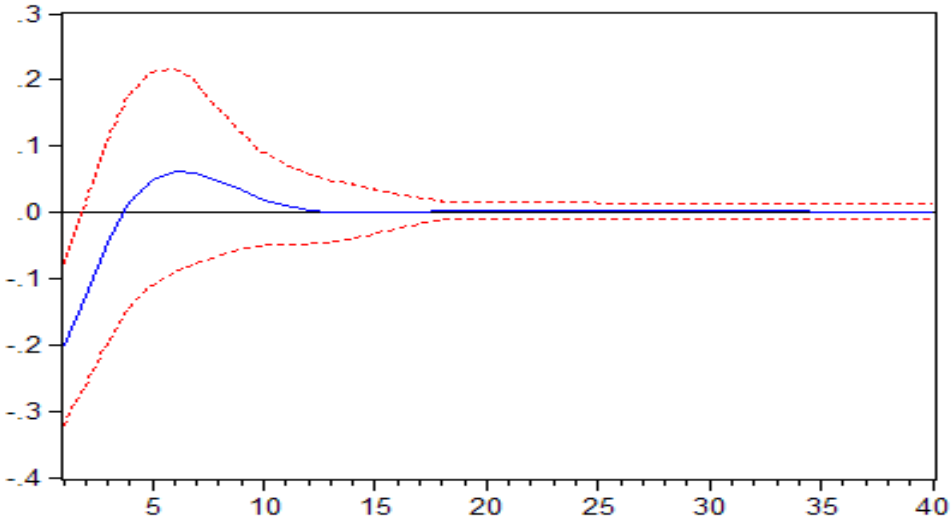
IRFs with the data 1999:Q2 to 2007:Q1[2]. The results are similar to those from the full sample data, but the sizes of the responses are much smaller than in the full sample period. The size of the price level relative to output is much smaller than for the full sample. Hence, we can conclude from these results that the price puzzle is reduced in the post currency crisis period.

Next, in order to examine the role of the banking sector in transmitting monetary policy, I investigate the impulse response of the loan premium (ϕ_t) to the monetary policy shock. The loan premium is defined as the extra cost to firms that borrow funds from banks instead of using internal finance, as in Bernanke, Gertler and Gilchrist (1998). Hence, the loan premium is calculated as the weighted average of loan rates to firms of deposit banks minus the returns on the one-year maturity monetary stablization bond. Since new information on the loan premium does not provide additional information to policymakers, I set the order of the state variables as $X_t^1 = [y_t, p_t, R_t, \phi_t]$. In line with data availability, I use data from 1999:Q2 to 2007:Q1.

The solid line in Figure 2 represents the IRF of loan premium to a one standard deviation positive interest rate shock, and the dotted lines display a 95% confidence interval. A positive interest rate shock reduces the loan premium for two periods. The loan premium response movement opposite to that of the policy rate implies that the banking sector supplying funds charges a small premium on loans in response to the positive interest rate shock. As a result, firms can borrow money with small interest costs compared to the case in which the loan premium moves in the same direction as the policy rate. This means, in turn, that firms which finance their factor costs do not reduce their factor inputs as much as they would in the case of a positive loan premium response to a positive interest rate shock. Therefore, the loan premium response shown in Figure 2 implies that the banking sector mitigates

[2] I omit confidence intervals because the confidence bands contain zero lines.

Figure 2: Impulse response of loan premium to an interest rate shock (%)



The solid lines represent impulse responses to a one-standard error shock, and the dotted lines represent 95% confidence intervals.

the effect of policy on the production sector.

2.2 Test of the Cost Channel Using an Interest Rate Augmented Phillips Curve

In this section, I investigate whether the cost channel of monetary policy transmission exists in Korea, by testing the direct effect of the nominal interest rate on inflation using a modified Phillips curve. The estimation model and method are based on the work by Ravenna and Walsh (2006). My model differs from them, however, in that I assume that firms use their own capital stock in the production process. Hence, firms' decisions on capital stock affect their price decisions.

The estimation model is given by equation (1) based on the modified Phillips

Table 1: Results of Estimation of Interest Rate Augmented Phillips Curves

A. 1991Q1-2007Q1	Γ	γ	ω_π	a	J-stat.
Parameters	1.905	0.270	0.395	0.317	4.211
	(0.288)	(0.067)	(0.064)	(0.092)	[0.837]
$a = 0$	5.325	0.635	0.153	0	10.906
	(2.036)	(0.096)	(0.058)		[0.282]
D-test	5.811	Wald test	0.311		
$(H_0 : a = 0)$	[0.015]	$(H_0 : a = 1)$	[0.576]		
B. 1999Q2-2007Q1	Γ	γ	ω_π	a	J-stat.
Parameters	1.149	0.167	0.585	0.450	1.090
	(0.094)	(0.060)	(0.028)	(0.585)	[0.997]
$a = 0$	1.240	0.237	0.577	0	1.161
	(0.105)	(0.056)	(0.026)		[0.999]
D-test	0.574				
$(H_0 : a = 0)$	[0.448]				

Numbers in ( ) represent standard deviations and those in [ ] denote p-values.

curve, which will be formally derived from the DSGE model in later section:

$$\begin{aligned} \hat{\pi}_t &= \tfrac{\Gamma\gamma}{\Gamma+\beta\gamma}\hat{\pi}_{t-1} + \tfrac{\beta}{\Gamma+\beta\gamma}\hat{\pi}_{t+1} + \tfrac{(1-\omega_\pi\beta)(1-\omega_\pi)}{\omega_\pi(\Gamma+\beta\gamma)}\hat{mc}_t + \zeta_t \\ &= \tfrac{\Gamma\gamma}{\Gamma+\beta\gamma}\hat{\pi}_{t-1} + \tfrac{\beta}{\Gamma+\beta\gamma}\hat{\pi}_{t+1} + \tfrac{(1-\omega_\pi\beta)(1-\omega_\pi)}{\omega_\pi(\Gamma+\beta\gamma)}(\hat{s}_t + a\hat{R}_t^L) + \zeta_t \end{aligned} \tag{1}$$

where ζ_t is the sum of the forecasting error $-\frac{\beta}{\Gamma+\beta\gamma}(\hat{\pi}_{t+1} - E_t\hat{\pi}_{t+1})$ and measurment error, β represents the time preference discount factor and ω_π denotes the degree of price stickiness. $0 \leq \gamma \leq 1$ is the weight of previous period inflation in the price decision process, and Γ is the parameter related to the decision on capital stock. $mc_t = \frac{R_t^L W_t/P_t}{MPL_t} = \frac{R_t^L s_t}{1-\alpha}$ is the real marginal cost of firms where s_t is the labor share of output and R_t^L denotes a nominal interest rate which is the interest cost of firms for financing factor costs. Parameters are estimated by GMM. In order to identify the parameters, I fix β first and then estimate others.

The only difference of equation (1) from the standard new Keynesian Phillips curve is that the nominal interest rate is added because of the existence of the cost channel of monetary policy. Hence, by testing the null hypothesis of $a = 0$, we can

determine whether the cost channel exists or not during the estimation periods. We define Z_t as an instrumental vector orthogonal to ζ_t. The moment condition then becomes

$$E_t\left(\left[\hat{\pi}_t - \frac{\Gamma\gamma}{\Gamma+\beta\gamma}\hat{\pi}_{t-1} + \frac{\beta}{\Gamma+\beta\gamma}\hat{\pi}_{t+1} + \frac{(1-\omega_\pi\beta)(1-\omega_\pi)}{\omega_\pi(\Gamma+\beta\gamma)}(\hat{s}_t + a\hat{R}_t^L)\right]|Z_t\right) = 0.$$

Inflation is measured by core CPI inflation, and for the nominal interest rate I use the call rate[3]. For $\hat{s}_t$, I use the labor income share as in Moon, Yun, and Lee (2004). All variables are detrended by HP-filter. The instrumental vector consists of the labor income share, real GDP gap, call rate, return on one-year maturity monetary stabilization bonds, core CPI inflation, and M2 with $t-2$ and $t-3$ time lags. A Newey-West method with four-period lags is applied to estimate the variance-covariance matrix.

Panels A and B in Tabel 1 show the results of estimation of modified Phillips curves for the full sample (1991:Q1-2007:Q1) and the post currency crisis sample (1999:Q2-2007:Q1), respectively. All estimated parameters are significantly different from zero under the 5% critical level, with the exception of the interest rate coefficient a for the post currency crisis sample. D-statistics to test the null hypothesis of the existence of cost channel is 5.81 in the full sample rejecting the null hypothesis, but in the post currency crisis sample cannot reject the null. These results imply that the cost channel of monetary policy transmission does not work in the post currency crisis period.

[3]For data availability, the interest cost for loans in the business sector is used only for the post currency crisis period (1999Q2 to 2007:Q1). Even if I use the call rate for this period, the main result is not changed.

3 The Model Economy

3.1 The Model

In this section, I build a DSGE model which includes the cost channel of monetary policy transmission based on a new Keynesian model. The active role of the banking sector is also added to the model suggested by Goodfriend (2004) and Goodfriend and McCallum (2006).

A. Households

A household h, which is indexed on a unit interval, supplies two different types of labor services ($N^f_{h,t}$, $N^b_{h,t}$) – to firms and the banking sector, respectively. Each household is assumed to maximize the following lifetime utility:

$$E_t \sum_{j=0}^{\infty} \beta^j \left[\frac{c_{h,t+j}^{1-\sigma}}{1-\sigma} - \psi \frac{(N^f_{h,t+j} + N^b_{h,t+j})^{1+\eta}}{1+\eta} \right] \tag{2}$$

where $\sigma > 0$, $\eta > 0$, $\psi > 0$, and $0 < \beta < 1$ denote the inverse of intertemporal elasticity of consumption, the inverse of elasticity of labor supply, the weight of labor in the utility, and the time preference discount factor, respectively.

Consumption goods are financed by the money balance from the previous period and wage income earned from firms in advance of producing output. The cash-in-advance (CIA) constraint is given by

$$P_t c_t \leq M_{h,t-1} - \frac{B^H_{h,t}}{R_t} + W^f_{h,t} N^f_{h,t} \tag{3}$$

where P_t, R_t, and $W^f_{h,t}$ denote the price of one unit of consumption good, the gross rate of return on risk free bonds, and the nominal wage for labor services used in the production process, respectively. The money balance at the end of period t ($M_{h,t}$) consists of the residuals of money from the goods market, the profits from firms

($DIV^f_{h,t}$) and the banking sector ($DIV^b_{h,t}$), the return on bonds, wage income from the banking sector ($W^b_{h,t}N^b_{h,t}$), and money transfer from the government ($T_{h,t}$):

$$M_{h,t} = M_{h,t-1} - \frac{B^H_{h,t}}{R_t} + W^f_{h,t}N^f_{h,t} - P_t c_t + DIV^f_{h,t} + DIV^b_{h,t} + B^H_{h,t} + W^b_{h,t}N^b_{h,t} + T_{h,t} \quad (4)$$

Nominal wages are determined by Calvo-type wage contracts. A $(1-\omega_N)$ fraction of households set their wages in the optimization process, and a ω_N fraction of them set their wages in accordance with the following rule;

$$W^k_{h,t} = \pi^\gamma_{t-1} W^k_{h,t-1} \quad (5)$$

where $k = f$ or b, which represent the two types of users of labor services $-$ firms and the banking sector. $0 \leq \gamma \leq 1$ denotes the weight of past inflation, and inflation is defined as $\pi_t \equiv P_t/P_{t-1}$.

The Euler equations are given by

$$E_t \sum_{j=0}^{\infty} \left[\frac{1-\theta_N}{\theta_N} \frac{\pi_j W^f_{h,t}}{P_{t+j}} U_{c,t+j} - U_{N_h,t+j} \right] N^f_{h,t+j} = 0 \quad (6)$$

$$E_t \sum_{j=0}^{\infty} \left[\frac{1-\theta_N}{\theta_N} \frac{\pi_j W^b_{h,t}}{P_{t+j}} \frac{U_{c,t+j}}{R_{t+j}} - U_{N_h,t+j} \right] N^b_{h,t+j} = 0 \quad (7)$$

$$\frac{1}{R_t} = \beta E_t \frac{P_t}{P_{t+1}} \frac{U_{c,t+1}}{U_{c,t}} \quad (8)$$

where $\pi_j \equiv \pi_t \times \pi_{t+1} \times ... \times \pi_{t+j-1}$ when $j \geq 1$ or 1 when $j = 0$. The first two equations imply that the nominal wages for $W^f_{h,t}$ and $W^b_{h,t}$ are set at the point where the marginal utility of consumption equals the marginal disutility from work. The only difference between (6) and (7) is that the marginal utility of consumption in (7) is discounted by the nominal interest rate. The labor income from firms is used for time t consumption. On the other hand, the labor income from the banking sector at time t involves time $t+1$ consumption. Since time t labor income from the

banking sector will be used for purchasing time $t+1$ period consumption, it relates to the time $t+1$ utility instead of the time t utility. We thus have to evaluate the time $t+1$ utility in (7) as current value. Equation (8) is a standard asset pricing equation. The subscription for the household specifier, h, is omitted in equation (8), because of the assumption of the existence of complete contingent claims markets[4].

B. A Final Good Producing Firm

A final good y_t is produced by a representative, perfectly competitive firm that uses the following Dixit-Stigliz technology:

$$y_t = \left(\int_0^1 y_{i,t}^{\frac{\theta_\pi - 1}{\theta_\pi}} di \right)^{\frac{\theta_\pi}{\theta_\pi - 1}} \tag{9}$$

where $y_{i,t}$ is an intermediate good produced by intermediate-good producing firm $i \in (0,1)$. The parameter $\theta_\pi > 1$ is the price elasticity of demand for the individual good i. The higher θ_π is, the closer the substitutibility among individual goods. The final good producing firm maximizes its profit given its output price P_t and input price $P_{i,t}$. The demand for good i is then driven by the Euler equation, and the output price can be obtained as follows:

$$y_{i,t} = \left(\frac{P_{i,t}}{P_t} \right)^{-\theta_\pi} y_t \tag{10}$$

$$P_t = \left(\int_0^1 P_{i,t}^{1-\theta_\pi} di \right)^{\frac{1}{1-\theta_\pi}} \tag{11}$$

C. Intermediate Good Producing Firms

A monopolistically competitive firm $i \in (0,1)$ produces an intermediate good $y_{i,t}$

[4]Refer to Erceg *et al.* (2000) for details.

using the following CES (constant elasticity of substitution) technology:

$$y_{i,t} = \begin{cases} K_{i,t}^{\alpha}(N_{i,t}^{f})^{1-\alpha} - \bar{Y} & \texttt{if} \quad K_{i,t}^{\alpha}N_{i,t}^{1-\alpha} \geq \bar{Y} \\ 0 & o.w. \end{cases} \tag{12}$$

where $\bar{Y} > 0$ and α denote the fixed cost of production and the steady state capital share of output, respectively. Labor $N_{i,t}^{f}$ is supplied by a representative firm which transforms differentiated labor services from households into aggregate labor N_t^f. The labor cost is financed by loan contracts and paid to workers in advance of production. $K_{i,t}$ denotes the capital stock of firm i at the beginning of period t. Each firm purchases investment goods in the goods market. The transition law of productive capital stock is given by

$$K_{i,t+1} = (1-\delta)K_{i,t} + I_{i,t} \tag{13}$$

where δ denotes the depreciation rate and $I_{i,t}$ is assumed to satisfy the following conditions: $I_{i,t} = I(\frac{K_{i,t+1}}{K_{i,t}})K_{i,t}$, $I(1) = \delta$, $I'(1) = 1$, and $I''(1) = e_{\psi}$.

Each firm follows a two-step optimization procedure. First, it minimizes its time-discounted total cost given the output and its price level. Second, it maximizes time-discounted profit with respect to its price with the cost function and the output price as given. Since firms are owned by households, all economic activities by firms should be evaluated as households' values. Let Λ_t denote a marginal value of one dollar to households,[5] which is given by $\Lambda_t = E_t\beta\frac{U_{c,t+1}}{P_{t+1}}$. Let $D_{i,t}$ denote the amount of loans to finance labor costs, $D_{i,t} = W_t^f N_{i,t}^f$. The borrowed money should be repaid with the gross interest rate $R_{L,t}$ at the end of period t, from time t sales revenue. Hence, the time t total borrowing cost becomes $R_{L,t}W_t^f N_{i,t}^f$. The periodic

[5]This type of discount factor expression is used in many general equilibrium studies, including CEE (2005), Jung (2004), Christiano and Eichenbaum (1995), and Dotsey and Ireland (1995).

total cost will be expressed as

$$TC_{i,t} \equiv R_{L,t} W_t^f N_{i,t}^f + P_t I_{i,t}.$$

Given the production function (12) and the transition law of productive capital stock (13), the firm chooses $N_{i,t}^f$ and $K_{i,t+1}$ by minimizing its time-discounted expected total cost.

$$E_t \sum_{j=0}^{\infty} \beta^j \Lambda_{t+j} TC_{i,t+j} \tag{14}$$

The first order conditions with respect to $K_{i,t+1}$ and $N_{i,t}^f$ are as follow

$$\beta E_t \lambda_{t+1} \rho_{i,t+1} = \lambda_t I' \left(\frac{K_{i,t+1}}{K_{i,t}} \right) + \beta E_t \lambda_{t+1} I \left(\frac{K_{i,t+1}}{K_{i,t}} \right) + \beta E_t \lambda_{t+1} I' \left(\frac{K_{i,t+2}}{K_{i,t+1}} \right) \frac{K_{i,t+2}}{K_{i,t+1}} \tag{15}$$

$$mc_{i,t} = \frac{R_t^L w_t^f}{MPL_{i,t}} \tag{16}$$

where $\lambda_t = P_t \Lambda_t$ and $\rho_{i,t} = w_t^f MPL_{i,t}/MPK_{i,t}$ and $w_t^f = W_t^f / P_t$ represent the implicit price of capital and the real wage, respectively.

Firms are assumed to adjust their prices based on a Calvo-type pricing mechanism. A $1 - \omega_\pi$ fraction of firms re-optimize their prices every period, but the remaining fraction simply set their prices as follows:

$$P_{i,t} = \pi_{t-1}^{\gamma} P_{i,t-1} \tag{17}$$

The above equation implies that, when firm i does not re-optimize after time t, its price in period $t + j$ becomes $P_{i,t+j} = \pi_j^{\gamma} P_{i,t}$. If we define P_t^* as the equilibrium price level chosen by price re-optimizing firms, then from (11) the average price in

period t becomes

$$P_t^{1-\theta_\pi} = (1-\omega_\pi)P_t^{*(1-\theta_\pi)} + \omega_\pi(\pi_{t-1}^{\gamma}P_{t-1})^{1-\theta_\pi} \tag{18}$$

Each firm then chooses $P_{i,t}$ to maximize its lifetime cash flow as follows:

$$E_t\sum_{j=0}^{\infty}(\omega_\pi\beta)^j\Lambda_{t+j}(\pi_j P_{i,t}y_{i,t+j} - TC_{i,t+j}) \tag{19}$$

The price decision process results in the following first order condition:

$$E_t\sum_{j=0}^{\infty}(\omega_\pi\beta)^j\lambda_{t+j}\left(\frac{\pi_j^{\gamma}}{P_{t+j}}\right)^{\theta_\pi} y_{t+j}\left(P_{i,t}^{*}\frac{\pi_j^{\gamma}}{P_{t+j}} - \frac{\theta_\pi}{\theta_\pi - 1}mc_{i,t+j}\right) = 0 \tag{20}$$

Each firm uses differenciated capital in the production process, the implicit capital price and real marginal cost are different across firms. The log linearized Phillips curve considering the relationship between the capital stocks of individual firms and inflation can be expressed as follows[6]:

$$\hat{\pi}_t = \frac{\Gamma\gamma}{\Gamma+\beta\gamma}\hat{\pi}_{t-1} + \frac{\beta}{\Gamma+\beta\gamma}E_t\hat{\pi}_{t+1} + \frac{(1-\omega_\pi\beta)(1-\omega_\pi)}{\omega_\pi(\Gamma+\beta\gamma)}\hat{mc}_t \tag{21}$$

where $\hat{mc}_t = \hat{s}_t + \hat{R}_{L,t}$ and Γ is a nonlinear function of model parameters given by $\Gamma = f(\epsilon_\psi, \omega_\pi, \beta, \gamma, \delta, \alpha, \theta_\pi)$. The slope of the aggregate supply curve represented by the Phillips curve depends upon the size of ω_π as follows:

$$\frac{\partial Slope\ of\ AS}{\partial\omega_\pi} = \frac{\beta\omega_\pi^2 - 1}{(\Gamma+\beta\gamma)\omega_\pi^2} < 0 \tag{22}$$

Hence, as ω_π rises, the slope of AS declines and the size of the inflation response to a positive interest rate shock shrinks.

[6]Refer to Woodford(2003) for further discussion on this topic.

D. Banking Sector

The banking sector supplies loanable funds (L_t^S) to firms, with the source of these funds being bond issuance (B_t^B). Hence, the resource constraint for funds is given by

$$\frac{B_t^B}{R_t} = L_t^S \tag{23}$$

The banking sector is assumed to produce the supply of loan using collateral and labor to monitor the use of funds[7].

$$\frac{L_t^S}{P_t} = FK_{t+1}^{\alpha_1}(N_t^b)^{1-\alpha_1} \tag{24}$$

where the left hand side represents the real supply of loans, and F and $1-\alpha_1$ denote the loan productivity parameter and the labor share in loan production, respectively.

The profit of the banking sector at the end of time t consists of the gross return on loan contracts minus the labor cost ($W_t^b N_t^b$) and bond payments (B_t^B) to bond holders

$$DIV_t^b = R_t^L L_t^S - W_t^b N_t^b - B_t^B \tag{25}$$

The first order conditions for maximization of profit are reduced to the following equation:

$$R_t^L = R_t + \phi_t \tag{26}$$

where $\phi_t = \frac{w_t^b}{MPL_t} = \frac{1}{1-\alpha_1}\frac{w_t^b}{FK_{t+1}^{\alpha_1}(N_t^b)^{-\alpha_1}}$. Equation (26) implies that the return on loan contracts is equal to the saving rate (or return on risk free bonds) plus the

[7]For details, refer to Goodfriend (2004) and Goodfriend and McCallum (2007).

marginal cost of producing loan supply.

E. Monetary Authority

The budget constraint of the government is assumed to be given by

$$M_t^S + \frac{B_t^C}{R_t} = M_{t-1}^S + B_t^C + T_t \tag{27}$$

This implies that money transfer is financed by issuing bonds and by seigniorage. Money is assumed to be supplied through open market operations ($B_t^C/R_t = -\Delta M_t^S$), and the interest rate rule is assumed to be given by

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_g} \left((E_t\pi_{t+1})^{a_\pi} \left(\frac{y_t}{y^*}\right)^{a_y}\right)^{1-\rho_g} e^{z_t} \tag{28}$$

where R denotes the interest rate level when inflation and output targets are met, and z_t represents the exogenous shock to interest rates, which the central bank cannot control.

F. Market Clearing Conditions

The market clearing condition for goods i becomes $c_{i,t} + I_{i,t} = y_{i,t}$. When we define $\bar{P}_t \equiv \left(\int_0^1 P_{i,t}^{-\theta_\pi} di\right)^{-1/\theta_\pi}$ and $\bar{y}_t \equiv K_t^\alpha (N_t^f)^{1-\alpha} - \bar{Y}$, the aggregate goods market clearing condition becomes

$$c_t + I_t = \left(\frac{\bar{P}_t}{P_t}\right)^{\theta_\pi} \bar{y}_t \tag{29}$$

The loan market, money market, and bond market clearing conditions are as follow:

$$L_t^S = W_t^f N_t^f \tag{30}$$

$$M_t^S = M_t \tag{31}$$

Table 2: Results of Policy Rule Estimation

$$E_t\left([r_t - \rho_g r_{t-1} - (1-\rho_g)(r^* - a_\pi \pi^* + a_\pi \pi_{t+1} + a_y \hat{y}_t)]z_t\right) = 0$$

	ρ_g	a_π	a_y	J-stat.
A. 1991:Q1-2007Q1	0.754	1.871	0.593	1.695
	(0.052)	(0.024)	(0.010)	[0.999]
B. 1999:Q2-2007Q1	0.850	0.345	0.617	1.120
	(0.004)	(0.006)	(0.004)	[0.999]

1. The numbers in ( ) represent standard deviations and those in [ ] denote p-values.
2. The instrumental variables are the call rate, output gap, core CPI inflation, M2 growth rate, and GDP deflator growth rate for the 1991:Q1-2007:Q1 sample and the call rate, output gap, core CPI inflation, CD rate and CPI inflation for the 1999Q2-2007:Q1 sample.
3. Time lags are used for instrumental variables.
4. Newey-West estimators with four lags are used for the standard deviations.
5. π^* is the inflation average during the sample period, and r^* is calculated with the constant term and other parameters.

$$B_t^B = B_t^H - B_t^C \tag{32}$$

3.2 Policy Simulation

A. Calibration

The parameters in the Phillips curve are from the previous section, and the policy rule parameters are estimated by GMM. The variables used in estimating the policy rule are the HP-filtered real GDP gap, the call rate and the core CPI inflation − all from 1991:Q1 to 2007:Q1 and from 1999:Q2 to 2007:Q1. The estimation results are shown in Table 2. They are all statistically significant, and the J-statistics imply that the instrumental variables have been choosen appropreiately for both sample periods. The interest rate inertial parameter (ρ_g) is 0.754 in the post currency crisis period, which is a little larger than the 0.851 from the full sample period. The weight of the output gap 0.618 in the post currency crisis period is also greater than the 0.594 for the full sample. However, the inflation weight during the post currency crisis period drops to 0.345 − from 1.871 in the full sample period[8]. The

[8]The parameters satisfy the stability conditions necessary to solve the model.

depreciation rate of capital stock δ is set at 4.3%, which from the estimates by Pyo (2003) is the quarterly average for all industries during 1987 to 1997. The elasticity of labor supply is set to be one. The capital share of output α is set to be 0.4, and the weight of labor in the utility is measured by the monthly average labor hours devided by total hours available as in Park and Shin (2000). I set the fixed costs in production $\bar{Y}$ to imply that the firms' profit is zero in the nonstochastic steady state. I set the steady state loan rate R^L to be the sum of the risk free rate and 1.43%, which is the weighted average of loan rates to firms of deposit banks during 1999 and 2007.

I set θ_π to imply that the steady state markup is 1.2. ω_N is set to imply that the frequencies of change in nominal wages are four and 2.8 quarters in the full sample and post-currency crisis periods, respectively. This reflects the fact that wage stickiness has declined since the currency crisis. I set F and θ_N as 20 and 6, respectively, and calculated α_1 and ϵ_ψ from the other steady state values in the model.

B. Policy Simulation Using the Baseline Model

Part A in Figure 3 displays the impulse responses of the macrovariables with the calibrated values from the post currency crisis data. A one standard deviation positive interest rate shock is given. The dotted lines are the empirical IRFs from the previous section. As shown in the second column of Table 4, the positive interest rate shock reduces output by 0.64% by raising the financial costs of firms. Consumption also decreases by 0.47%, because of the reduction of labor income and the higher price of goods relative to the price of bonds. Investment decreases by 0.99% after the shock.

Inflation rises by 0.1% initially. It falls below the steady state value three quarters after the shock, which implies that, at a short horizon, the effect of monetary

Table 3: Parameters

	'91-'07	'99-'07	
β	$1.0512^{1/4}$	$1.0173^{1/4}$	Time discount factor
R^L	1.016	1.0078	Loan interest rate in the steady state
η	1	1	Inverse of labor elasticity
α	0.4	0.4	Capital share of output
α_1	0.5026	0.4820	Collateral share of loan production
δ	0.0107	0.0107	Depreciation rate
ψ	2.46405	2.48104	Weight of labor in utility function
σ	2	2	Inverse of intertemporal elasticity of consumption
ϵ_ψ	83.3155	70.6931	Capital adjustment parameter
γ	0.27008	0.16714	Inflation index parameter
ω_π	0.39569	0.58576	Degree of price stickiness
ω_N	0.75	0.65	Degree of wage stickiness
θ_π	6	6	Elasticity of substitution of intermediate goods
θ_N	6	6	Elasticity of substitution of labor services
ρ_g	0.75445	0.85086	Interest rate smoothing parameter
ρ_π	1.87109	0.34516	Weight of inflation in the policy rule
ρ_y	0.59369	0.61758	Weight of output gap in the policy rule
Γ	1.90527	1.14970	Parameter for individual capital stock
F	20	20	Parameter in the loan production function

policy through the cost channel is dominant over the effect through the reduction of aggregate demand. At a long horizon, however, the effect of the monetary policy shock on demand is greater than it is on supply.

The inflation response in the full sample period can be seen in part B of Figure 3 and the third column of Table 4. The inflation response in the post currency crisis period is much smaller than that in the full sample period, in which the initial inflation response is 0.24%. From this result, we can conclude that the cost channel effect of monetary policy transmission is weakened after the currency crisis, which confirms the empirical results from the previous section.

This result stems partially from the fact that the degree of price stickiness increases from 0.395 in the full sample period, as shown in the fourth column of Table

Table 4: Initial responses of macrovariables to monetary policy shock

	A		B		C	
	'91-'07	'99-'07	'91-'07	'99-'07	'91-'07	'99-'07
$\hat{R}_t$	0.973	0.942	0.766	0.786	0.809	0.775
$\hat{\phi}_t$	-1.000	-0.906	-	-	-	-
$\hat{c}_t$	-0.439	-0.466	-1.080	-1.637	-1.071	-1.708
$\hat{I}_t$	-0.645	-0.993	-1.516	-3.204	-1.457	-3.403
$\hat{y}_t$	-0.487	-0.636	-1.182	-2.143	-1.163	-2.255
$\hat{\pi}_t$	0.242	0.099	-0.221	-0.453	0.034	-0.357
$\hat{R}_t^L - \hat{R}_t$	$-0.46 \cdot 10^{-3}$	$-0.65 \cdot 10^{-3}$	-	-	-	-

1. One-standard deviation shocks are given.
2. Columns A, B, and C represent the baseline model, the model without the cost channel, and the model without a loan premium, respectively.

1, to 0.585 in the post currency crisis period, since the size of the positive inflation response to the contractionary monetary policy shock decreases as the slope of the aggregate supply curve becomes less stiff (see equation (22)). In the post currency crisis period, the slower pass-through of production costs to output prices dramatically reduces the cost channel effect of monetary policy.

The weak cost channel effect since the currency crisis also comes from the fact that the parameter ϵ_ψ, which governs the capital adjustment cost, falls from 83 to 70 in the post currency crisis period, as shown in Table 3. This implies that in the post currency crisis period firms can adjust their capital stock with relatively small costs compared to during the full sample period. The investment responses for the two sample periods to the same amount of shocks conform with this argument. Investment falls by 0.64% in the full sample period and by 0.99% in the post currency crisis period, suggesting that investment reacts more sensitively to the policy shock since the currency crisis, because of the smaller capital adjustment cost.[9] Hence, the increase in monetary policy effect through changing of aggregate demand weakens

[9]This result comes from the assumption of the unit user cost elasticity of capital. If we take into account the argument by Kim (2006) that the user cost elasticity of capital falls after the currency crisis, we could reach the opposite result.

the cost channel effect further.

Next, the direction of the loan premium response (ϕ_t) in Figure 3 is similar to the empirical IRF. A positive interest rate shock reduces the loan premium by 0.91% in the post currency crisis period, since the increased interest rate reduces firms' demand for funds, and in turn reduces the real marginal cost of loan supply in the banking sector. In the full sample period, the loan premium response to the contractionary monetary policy shock is reduced by 1.0%. Since the movement of the loan premium response in a direction opposite to that of the policy rate implies that the banking sector attenuates the effect of policy on the production sector, the simulation results suggest that the size of banking sector attenuation of the policy effects has decreased since the currency crisis.

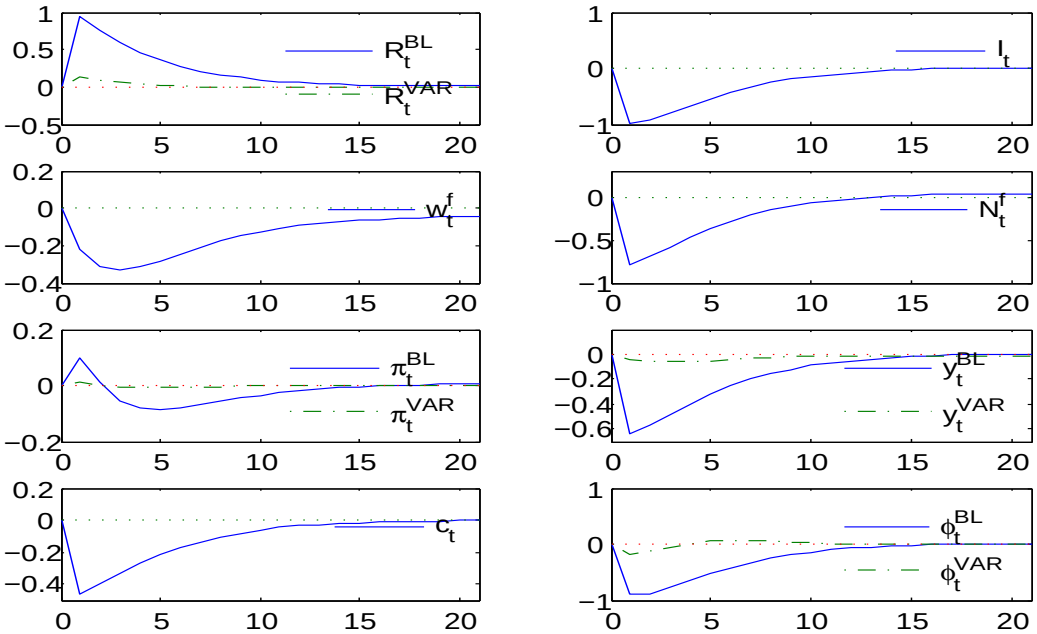
C. Without the Cost Channel

Figure 4 displays the impulse responses of the macrovariables to the same size of contractionary monetary policy shock as in the baseline case, but without the cost channel. Given the calibrated parameters, all responses are amplified relative to the baseline case, with the exception of the nominal interest rate and real wages.

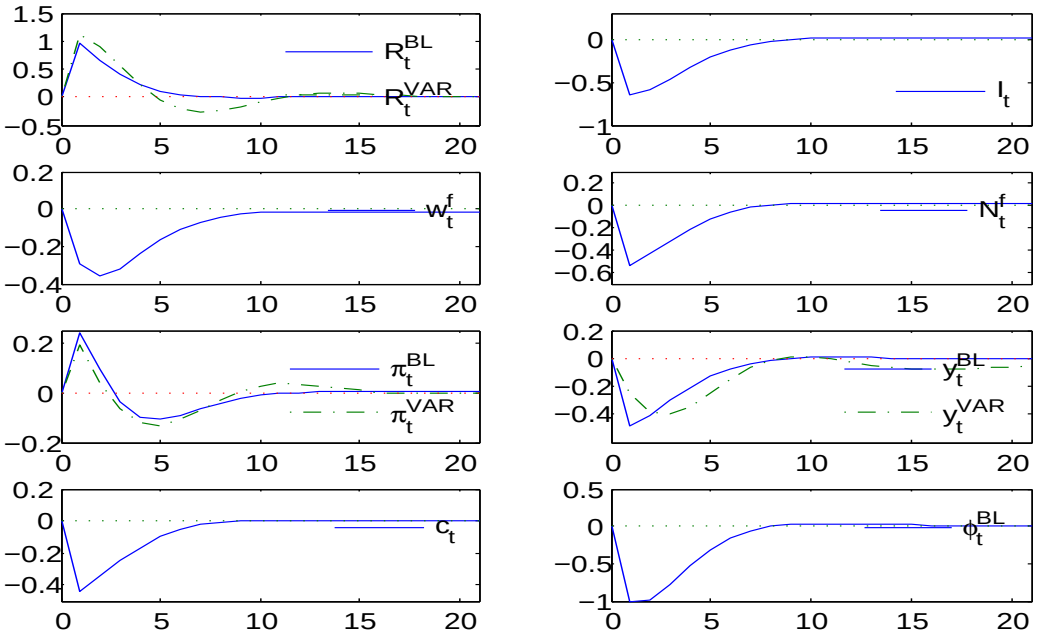
Without the cost channel, the increase in the nominal interest rate reduces inflation; hence the real interest rate, which is the relative price of the consumption goods, rises. On the other hand, when the cost channel works in the economy, the increased nominal interest rate could cause inflation to increase as in the previous simulation exercise. In this case, the real interest rate could rise too, if the size of the inflation response is less than that of the nominal interest rate. However, the size of the positive real interest rate response in the model with the cost channel effect cannot exceed that in the model without one. Therefore, the response of real interest rates in the case without the cost channel is greater than it is in the case with the cost channel; hence, the reduction in consumption is also greater.

Figure 3: Impulse Responses to an Interest Rate Shock

A. 1999Q2 - 2007Q1 (%)



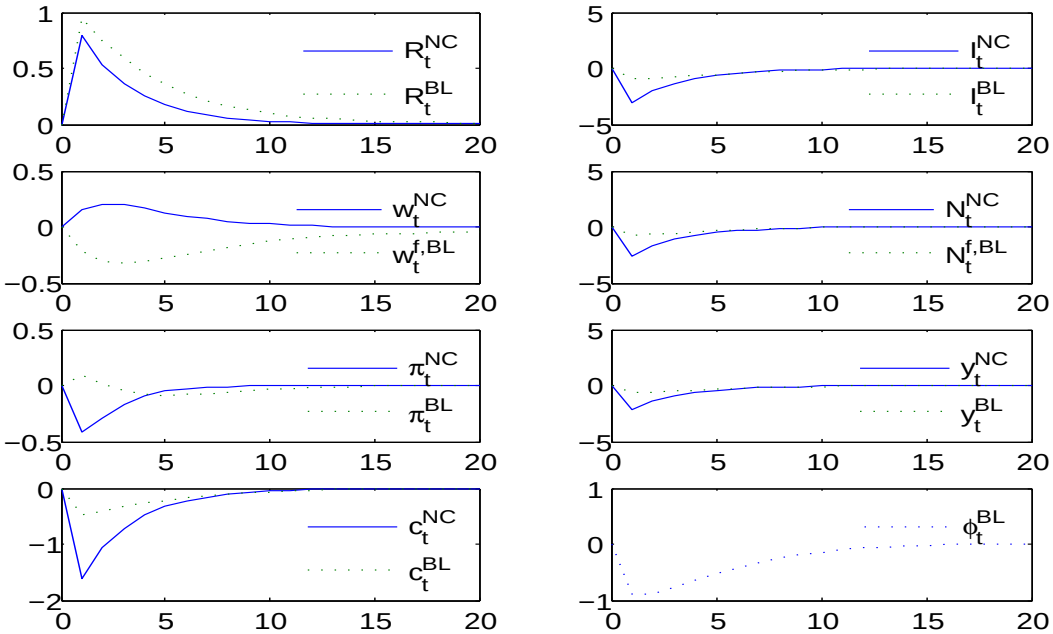
B. 1991Q1 - 2007Q1 (%)



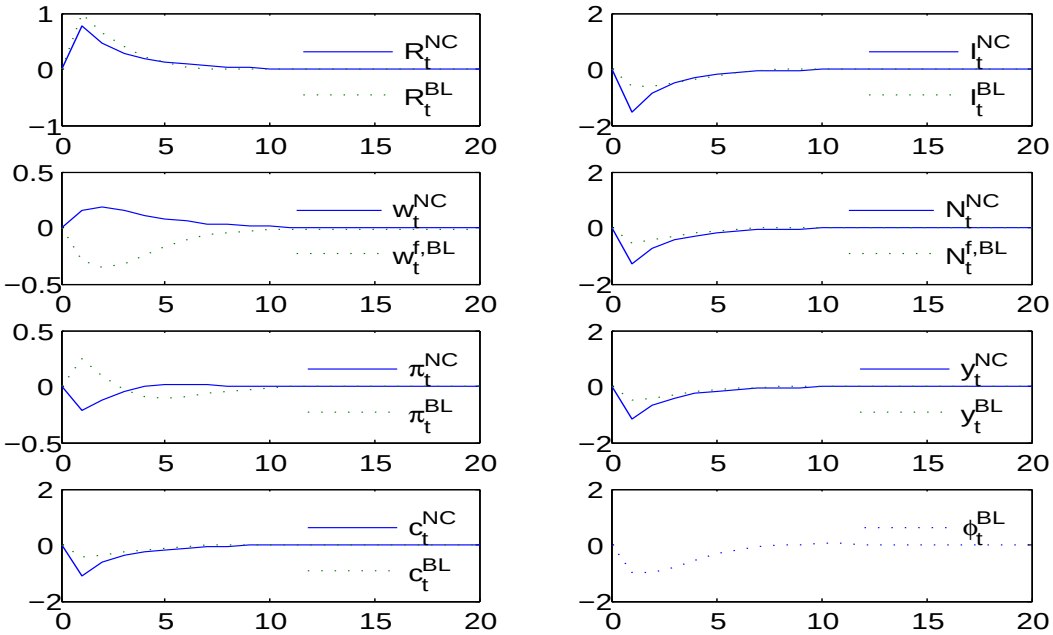
The superscript BL represents the baseline model IRFs, and the superscript VAR represents the estimated IRFs from section 2. R_t, N_t^f, w_t^f, π_t, c_t, I_t, y_t, and ϕ_t denote the nominal interest rate, labor service for producing goods, real wage for N_t^f, inflation, consumption, investment, output, and loan premium, respectively.

Figure 4: Impulse Responses to an Interest Rate Shock without the Cost Channel

A. 1999Q2 - 2007Q1 (%)



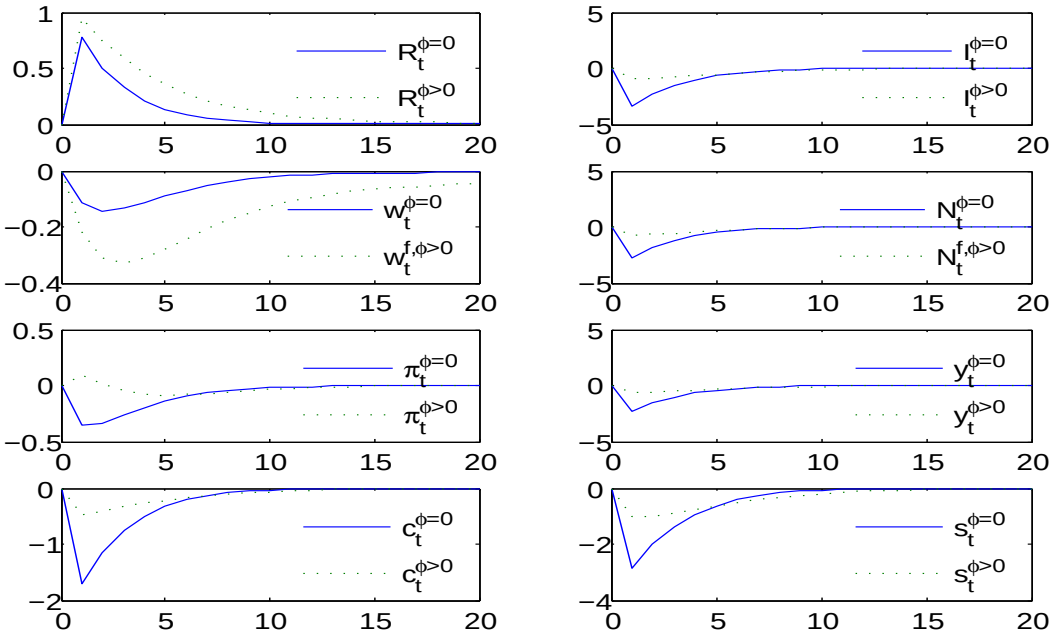
B. 1991Q1 - 2007Q1 (%)



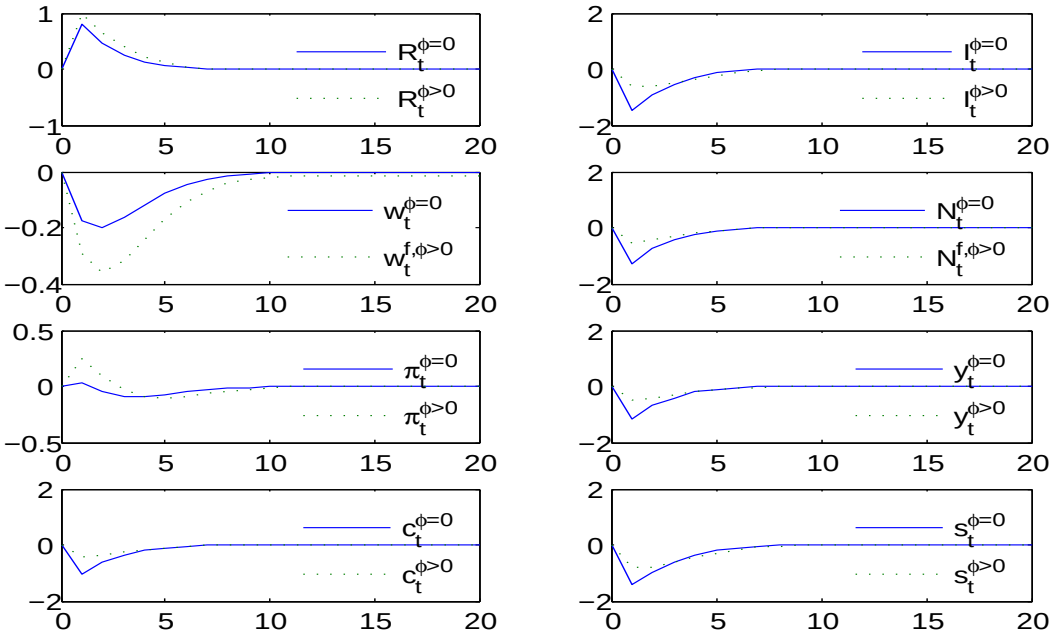
The superscript BL represents the baseline model IRFs, and the superscript NC represents the IRFs without a cost channel of monetary policy. R_t, N_t^f, w_t^f, π_t, c_t, I_t, y_t, and ϕ_t denote the nominal interest rate, labor service for producing goods, real wage for N_t^f, inflation, consumption, investment, output, and loan premium, respectively.

Figure 5: Impulse Responses to an Interest Rate Shock without a Loan Premium

A. 1999Q2 - 2007Q1 (%)



B. 1991Q1 - 2007Q1 (%)



The superscript $\phi > 0$ represents the baseline model IRFs, and the superscript $\phi = 0$ represents the IRFs without a loan premium. R_t, N_t^f, w_t^f, π_t, c_t, I_t, y_t, and ϕ_t denote the nominal interest rate, labor service for producing goods, real wage for N_t^f, inflation, consumption, investment, output, and loan premium, respectively.

A huge drop in consumption demand reduces labor demand and output by a large amount. In turn, investment falls greatly. Since the cost channel does not exist, inflation falls purely by the reduction in aggregate demand.

D. Without a Loan Premium

Figure 5 displays the impulse responses of macrovariables to the same size of contractionary monetary policy shock as in the baseline model, but without a loan premium. In this case, the banking sector produces loan supply efficiently; hence the return on the supply of loans is equal to the risk free rate, $R_{L,t} = R_t$, or the deposit rate. The initial responses of the state variables are shown in columns 6 and 7 in Table 4, for the full sample and post currency crisis periods, respectively.

The inflation response clearly shows that the effect of monetary policy through the cost channel is much smaller than the effect through changing of aggregate demand. The reason that the cost channel effect is weakened compared to the case with the baseline model is that, in the baseline model, the banking sector produces the supply of loans with a positive loan premium over the deposit rate (the risk free rate). This additional cost in supplying loanable funds generates a high wage bill financing cost to firms, compared to the case in which there are no additional costs for supplying loanable funds. Hence, the total labor cost of firms is also higher, and firms reduce their outputs more in response to the positive interest rate shock than in the case where there is no loan premium.

The direction of the inflation response depends upon the size of the monetary policy effect through the cost channel relative to that through aggregate demand. We can compare these two effects in the Phillips curve (21), which imply that the inflation response depends upon the relative sizes of the labor income share ($\hat{s}_t$) and the interest cost of loans ($\hat{R}_{L,t}$). The response of $\hat{R}_{L,t}$ provides the direct effect of cost channel. On the other hand, the response of $\hat{s}_t$ measures the partial

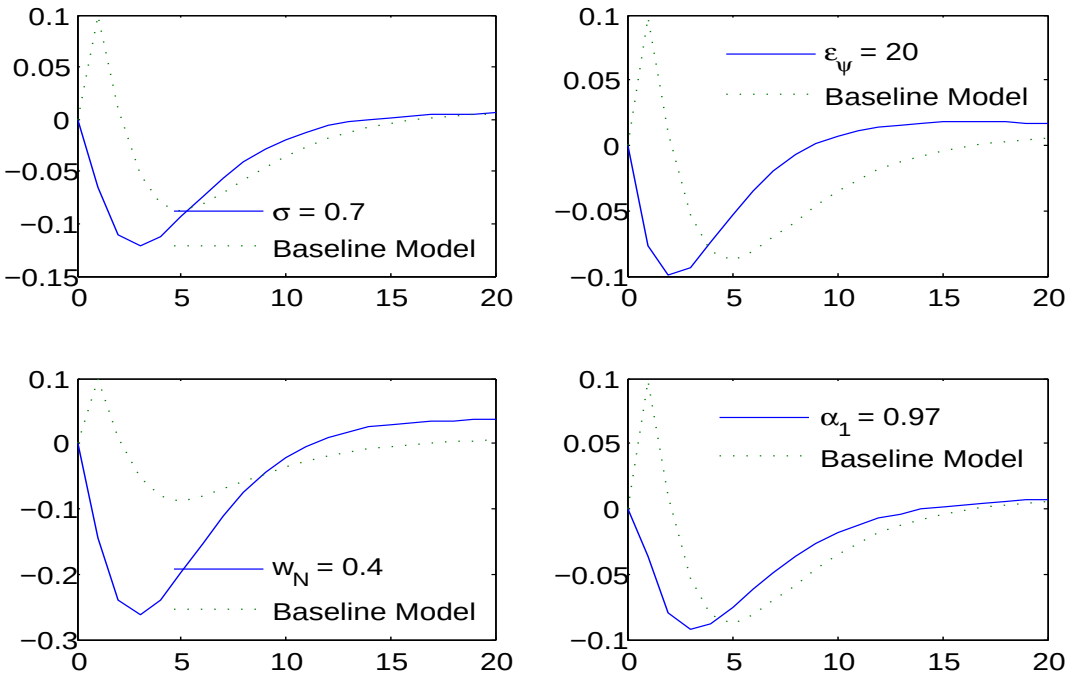
change in aggregate demand by the change in labor income, which is one partial source of consumption expenditure. As shown in Figure 5, the response of the nominal interest rate without a loan premium ($\phi_t = 0$) is much smaller than that in the baseline model, implying that the direct effect through the cost channel is much smaller in the model without a loan premium than it is in the baseline model ($\phi > 0$). Moreover, the response of $\hat{s}_t^{\phi_t=0}$ is greater than the response of $\hat{s}_t^{\phi_t>0}$, which implies that the relative change of labor income is larger in the model without a loan premium. Therefore, the source of consumption expenditure financing is reduced by a relatively large amount in the model without a loan premium, and this amplifies the size of the consumption reduction.

In the model without a loan premium, in summary, the direct effect of monetary policy through the cost channel shrinks, but the size of the monetary policy effect through reduction of aggregate demand grows. That is, when the banking sector supplies loans efficiently, the positive interest rate shock reduces inflation even if there is a cost channel of monetary policy transmission, because the size of the cost channel effect relative to that of aggregate demand reduction is smaller in the model without a loan premium than it is in the model where the banking sector supplies loans with a positive premium. Hence, as the banking sector supplies loans efficiently, the effectiveness of monetary policy can be raised in that the sizes of the reduction in aggregate demand and of the negative inflation response to a positive monetary policy shock become larger.

E. Sensitivity Analysis

The impulse responses in the previous exercises could depend critically upon the sizes of the model parameters. In this section, I examine which parameters are important in generating results showing that the cost channel is a dominant monetary policy transmission channel. I focus mainly on four different parameters

Figure 6: Sensitivity Analysis



The dotted lines plot the inflation responses with the baseline model parameters, and the solid lines plot the inflation responses with the changing parameters shown in the different boxes.

– σ, ϵ_ψ, ω_N, and α_1 – and explain the logic behind why and how these parameter values change the direction of the inflation response.

The numbers shown in Table 5 are the sizes of the initial inflation responses to a 100 basis point positive interest rate shock when four different parameters are individually changed. The baseline parameter values for the post crisis sample period are used.

The second column of Table 5 shows the initial inflation response of 0.105 to the positive interest rate shock, implying that the cost channel effect is dominant in the baseline case. The third coulmn shows that the initial inflation response is 0.182 when the inverse of the intertemporal elasticity of consumption (σ) is raised from 2 to 10. We can see clearly that the cost channel becomes more dominant than in the baseline case. A higher σ means that it is more difficult for households to

Table 5: Sensitivity Analysis

	Baseline Model	$\sigma : 2 \rightarrow 10$	$\epsilon_\psi 70 \rightarrow 80$	$\omega_N : 0.65 \rightarrow 0.85$	$\alpha_1 : 0.48 \rightarrow 0.9$
$\hat{\pi}_t$	0.105	0.182	0.115	0.179	0.091

For the baseline model, the parameter values for the post currency crisis period are used. Specifically, $\sigma = 2$, $\epsilon_\psi = 70$, $\omega_N = 0.65$, and $\alpha_1 = 0.48$ are used for the baseline model.

replace current consumption with future consumption. Because substitutability is low, households do not reduce current consumption as much as in the case where substitutability is high, given the same size of interest rate shock. Hence, the higher σ is, the more likely the cost channel effect is to be dominant over the reduction of aggregate demand due to the positive interest rate shock.

When the capital adjustment coefficient, ϵ_ψ, rises from 70 to 80 as shown in the fourth column of Table 5, the initial inflation response also rises from 0.105 to 0.115, which implies that the cost channel becomes more dominant. When ϵ_ψ is high, the cost of capital adjustment is high and, in turn, additional investment in capital stock becomes more difficult. Therefore, the size of reduction in aggregate demand to the positive interest rate shock is smaller than in the case where the capital adjutment cost is low.

I next change ω_N from 0.65 to 0.85, and the initial inflation response to the positive interest rate shock rises to 0.179, as shown in the last column of Table 5. As nominal wages become stickier, firms tend to reduce labor input more in response to the positive interest rate shock, with price adjustment difficult, they rely more on quantity adjustment instead. Hence, as ω_N becomes higher, the size of the reduction in output is greater than in the case where wages are more flexible (lower ω_N).

Lastly, as α_1 rises, the banking sector can supply loanable funds with lower monitoring costs. The funds can hence be supplied more efficiently with less loan premium. Therefore, the higher α_1 is, the smaller the firms' financing costs, which implies that the cost channel effect is less likely to be dominant.

In summary, the answer to the question of which monetary policy transmission channels are dominant depends upon the relative sizes of the model parameters. In my model economy, the cost channel effect which changes aggregate supply is smaller than the effect of changing aggregate demand when $\sigma < 0.960$, $\epsilon_\psi < 31.367$, $\omega_N < 0.510$, and $\alpha_1 > 0.965$, respectively. Figure 6 displays the inflation responses to a positive interest rate shock with different parameter values. The dotted lines are from the baseline model, and the solid lines from the cases when parameter values are changed as shown in the figure. As we can see from the figure, the cost channel effect is less dominant as σ, ϵ_ψ, and ω_N decrease, and as α_1 increases.

4 Summary and Conclusion

This paper has examined the cost channel effect of monetary policy in the Korean economy, under the DSGE model framework. Specifically, in order to see whether the size of the cost channel effect has changed since the 1997 Korean currency crisis, I separated my sample period into two parts − a full sample period and a post currency crisis period. The empirical findings are as follow. In the full sample period (1991:Q1 to 2007:Q1), a price puzzle is observed which a positive inflation response to the positive interest rate shock is generated at a short horizon. In the post currency crisis period (1999:Q2 to 2007:Q1), however, the size of inflation response is negligible. In order to test whether these inflation responses come from the cost channel effect, I estimated an interest rate augmented Phillips curve derived from the DSGE model. The estimation results are consistent with those from the VAR impulse response analysis. In the full sample period, the nominal interest rate has a direct effect on inflation, but we can not observe such a direct relationship between the nominal interest rate and inflation in the post currency crisis period.

Based upon these empirical findings, I added the cost channel of monetary policy

transmission to the DSGE model. Firms are assumed to finance their labor costs, and hence the change in policy rate has a direct effect on firms' decision-making processes. Various policy simulations were practiced for the two separate time periods. As in the empirical analysis, the model showed the positive inflation responses to the postive interest rate shock in both periods, but with the size of response in the post currency crisis period much smaller than that in the full sample period, even if the cost channel is assumed. The stronger effect of the cost channel in the full sample period can be explained by the fact that, before the currency crisis, firms continuously used external finance in the production process. Since the currency crisis, however, firms have tried to improve their financial conditions by using less external finance. Moreover, as firms have changed their output prices less frequently in the low inflation period (the post currency crisis period) than in the pre-currency crisis period, the pass-through of factor costs to goods prices has been delayed. Hence, the cost channel effect has become negligible in the post currency crisis period.

This paper also considered the role of a banking sector which produces loan supply and transfers the effects of monetary policy to the rest of the private sector. When the banking sector produces its loan supply with a positive monitoring cost, the interest costs of firms in financing labor costs is determined by the sum of the deposit rate (or the risk free bond rate) and the loan premium which is the real marginal cost of producing loan supply. The policy simulation showed that a positive interest rate shock reduces the demand for loans. In turn, it reduces the real marginal cost of loan production, and hence the loan premium declines. The decline in the loan premium reduces firms' production costs. Hence the banking sector mitigates the effects of monetary policy on firms.

When the loan premium is set at zero, that is, when the banking sector supplies loans efficiently, the cost channel effect of monetary policy is much smaller than

the effect through the changing of aggregate demand. Since firms can finance with small interest rate costs without an extra interest cost (loan premium), the monetary policy effect through the changing of aggregate demand is very likely to be dominant, as the banking sector supplies loan efficiently even in the presence of the cost channel. This implies that, given the existence of the cost channel, the central bank can reduce undesirable output price movements by enhancing efficiency in the banking sector.

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