The cost channel of monetary policy and inflation behavior in china*

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Abstract

This paper derives an empirical test model of the cost channel on the basis of a New-Keynesian general equilibrium model, i.e., an Interest Rate Augmented Phillips curve, and utilizes GMM Estimation to explore the significance, intensity, and time-varying nature of the cost channel based on quarterly data from 1995 to 2014 in China. The empirical analysis finds: First, compared to the traditional channel, the cost channel in China appears to be quite significant and presents strong time-varying characteristics. Additionally, both the traditional demand-side channel and the supply-side cost channel fail to describe the dynamic behavior of inflation. Second, in the process of two-round price rises, in 2007 and from 2010 to the first half year of 2011, the tight monetary policy resulted in rising inflation, and the cost channel had a significant impact on the price rises. Furthermore, the above-mentioned research results remain robust to various financing rates. Finally, we propose corresponding policy advice based on our findings.

Keywords: monetary policy; interest rate augmented Phillips curve; inflation; cost channel; TVR-VAR model

JEL Classification: E31, E32, E52

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1 Introduction

According to traditional macroeconomics theory, tight monetary policy can push down inflation. This is basically to analyze monetary policy transmission from the demand side, for example, monetary policy, either directly or indirectly, has an impact both on consumption expenditure and on demand by use of interest rate channels, credit channels, and wealth channels, etc. (Mishkin , 2007) . Especially, under tight monetary policy, the rise in interest rates will increase the opportunity cost of holding currency and investment based on Liquidity Preference Theory, and a rational economic person will reduce demand because of the decrease of actual money balance, thereby relieving the inflation problem.

The point of view of reducing aggregate demand and then pushing down inflation by use of tight monetary policy has been the consensus in both theory and practice in the long term, but it ignores the impact of monetary policy on the supply side (Yiming, Wang, and Dachang Cai, 2012). Chowdhury et al. (2006), Ravenna & Walsh (2006), and Tillmann (2008), etc., pointed out that the tight monetary policy shock might make the price and interest rate move in the same direction in the short run—this is the so-called price puzzle, whose theoretical mechanism is based mainly on the cost channel of the supply side. The basic assumption of this theory is that manufacturing enterprises need external funding to provide working capital in the process of production. Then, when the financing interest rate goes up, the margin production cost will go up accordingly, resulting in reduced output. Given that the demand remains unchanged in the short run, the demand exceeding supply will lead to the price rise, which is the phenomenon we observe—that the price and the interest rate move in the same direction.

The existence of the cost channel makes the adjustment to monetary policy become complicated, and the accuracy of policy adjustment is hard to control, with even the basic adjustment goal being hard to ensure. However, the core contents that monetary theory, and even the whole macroeconomics theory, pay attention to are: what are the short-term and long-term impacts of adjustment of the reserve requirement ratio and benchmark interest rate on output and inflation? Is it feasible to push down the trend of inflation by use of tight monetary policy, including tightening credit, or by increasing the reserve requirement ratio, the benchmark interest rate, and the interbank interest rate? The answer to these questions is very important to the theory and practice of monetary policy.

2 Literature review

Research on the cost channel of monetary policy began with Seelig (1974). Seelig discussed the interest rate and financing cost based on the Markup Pricing Model and pointed out that the inflation in 1950–60s cannot be attributed to the rise of the interest rate, because the level of the interest rate should be doubled to have an impact on the price. Subsequently, many scholars followed this idea and performed further analysis on the cost channel of monetary policy.

Many Western scholars have demonstrated the existence of the cost channel. Barth & Ramey (2001) utilized industry data in the US and other macroeconomics data to explore the technology shock, demand shock, and Taylor-Rule shock of monetary policy and found evidence that the transmission of monetary policy shock has a significant cost channel effect; the evidence for cost channel effects was much stronger from 1959 to 1979 than from 1983 to 1996, which may be related to debt-service burdens. Sims (1992) demonstrated that the tight monetary policy shock will make the money stock and output decline in the short term and that the responses of prices to interest rate shocks are positive,[1] which aggravates the inflation and results in a "price puzzle." Some scholars, such as Blinder (1987) , Fuerst (1992) , Christiano & Eichenbaum (1992) , Christiano et al. (1997) , Farmer (1984 , 1988a , 1988b) and Barth & Ramey (2001), followed this idea and used a Macro general equilibrium model to explore the impact of monetary policy transmission on the supply side. The interpretation based on the cost channel has received wide attention and recognition from most

[1] Among the five countries, the positive response is strong and persistent only in France and Japan. In the other countries the responses are weaker and eventually become negative. The results indicate that the phenomena of the inflation aggravation due to tight monetary policy is short-term.

scholars. According to this point of view, monetary policy transmission has a cost channel, which affects aggregate supply by affecting the cost of manufacture, and then affects inflation. Christiano et al. (2005) presented a model embodying moderate amounts of nominal rigidities, which accounts well for their estimate of the dynamic response of the US economy to a monetary policy shock, and confirmed the existence of a cost channel. Ravenna and Walsh (2006) pointed out that a monetary policy shock will have a more significant impact on inflation through the cost channel when the marginal cost of enterprise directly depends on the nominal interest rate and analyzed optimal monetary policy on the basis of Welfare Based Loss Function. Chowdhury et al. (2006) conducted similar research, which tested and estimated the relevance of the cost channel for inflation dynamics in G7 countries by establishing a mixed New Keynesian Phillips Curve. The results show that, due to the difference in financial systems and the transmission degree of the interest rate, the cost channel is not significant in Germany and Japan, while the monetary policy shock can immediately be transmitted to the cost of working capital in enterprises through the cost channel in England and the US, with an intensely competitive financial market, resulting in reduced output and inflation deterioration. Tillmann (2008) found that the cost channel adds significantly to the explanation of inflation dynamics in forward-looking sticky-price models for the US, the UK, and the Euro area within a New Keynesian Phillips curve framework. Additionally, some scholars have not found a significant cost transmission effect. For example, by estimating a dynamic stochastic general equilibrium (DSGE) model with sample data from 1959 to 2004, Rabanal (2007) found that the tight monetary policy shock cannot generate an increase of inflation in the short term. The reason is that the cost transmission effect will be significant only when the supply-side effects of monetary policy dominate the demand-side effects.

Compared to the Western research with respect to the cost channel, Chinese scholars have been a little late to commence relevant studies, and the research methodologies and contents are very limited. Fangping Peng and Yujun Lian (2010) conducted an empirical analysis based on a nonlinear smooth panel model and found that the cost channel is very significant. Jianli Sui et al. (2011) used the Bayesian statistical inference method to measure the validity of monetary policy in China from 1992 to 2009 and found that an unexpected tight monetary policy shock will result in moderate inflation. Hai Jiang and Zhuzhen Chu (2011) adopted a New Keynesian analysis framework and took advantage of a SVAR model and GMM estimation method to analyze the cost channel of monetary policy transmission. The results show that the cost channel exists in China. Yang Qi and Xin Liu (2011) obtained similar findings. Most of the above-mentioned research is based on an augmented Phillips curve, and the conclusions are nearly the same; however, the breadth and depth of research need to be further enhanced.

In general, current research on the cost channel has made certain preliminary achievements, and Western scholars have arrived at a consensus on the existence of the cost channel and its premises. According to the existing literature, Chinese scholars have not paid much attention to the cost transmission mechanism. Compared to Western research, Chinese literature has a very significant limitation; the sample is too small. For example, Hai Jiang and Zhuzhen Chu (2011) sampled data from the first quarter of 1996 to the first quarter of 2010, totaling 17 periods, while Yang Qi and Xin Liu (2011) sampled 12 periods of quarterly data. Different countries have different characteristics of economic activities, and economic activities differ in different periods, even in the same country. This is especially true for China, as an emerging and rapidly developing economic entity. Therefore, the sample data will affect the conclusions of research to a large extent. Furthermore, most domestic research has neither conducted robust tests nor analyzed the relevant nature of the cost channel. Thus, this paper will use broader sample data to analyze the cost channel in China and obtain more robust research conclusions, in addition to analyzing the intensity and time-varying nature of the cost channel.

3 Theoretical study on cost channel

This paper will set up a theoretical model of the cost channel of monetary policy shock transmission by use of a general equilibrium model within a New Keynesian framework. A general equilibrium model is the main-stream analysis tool in current macroeconomic analysis, and the relevant quantitative method has been becoming increasingly important in the toolbox of quantitative macroeconomists. A general equilibrium model uses a State Space Model to estimate the equilibrium value of variables, and this method has an irreplaceable advantage when analyzing non-observable variables (Jieqiu Wan and Tao Xu, 2011).

3.1 Theoretical model

The general equilibrium model adopted by this paper includes four types of economic entities: Firm, Household, Bank, and Government. We assume: (1) There are many manufacturing firms I, which constitute the continuum of measure unity with measure one, $i \in [0,1]$, and the intermediate product market is monopolistic competition, while the final product market is perfect competition. This assumption is in line with the current asymmetric situation that the upstream market is monopolistic, but the downstream market is competitive (Ruiming Liu and Lei Shi, 2011). (2) The households in the market are homogenous, and they arrange their consumption and labor reasonably to maximize utility under the budget constraint. (3) The financial market that the banks pay in is perfectly competitive. The banks take deposits from the households and make loans to firms, and the governments maintain the budget balance. It should be noted that this paper differs from the classic literature, such as Chowdhury et al. (2006), because the assumption of our model is that the firm will set the optimal price based on the market situation and not peg it to the inflation of the last period, thereby meaning that the derived empirical model does not have a first-order lag term. According to the empirical results, this assumption improves the goodness of fit of the data in China.

1. Firm: Assuming that the firm making intermediate products is monopolistic competitive, and its production function is:

$$y_{it} = a_t l_{it}^{1-\alpha} x_{it}^{\alpha} \tag{1}$$

Where y_{it} is intermediate product, a_t stands for productivity, l_{it} is the labor input of firm I, and x_{it} is the material input of representative household. Assume that the input in the current period of the two above captioned production factors needs to be financed by bank, and the financing amount is $loan_{it}$, then the firm will face the liquidity constraint:

$$loan_{it} \geq p_t w_t l_{it} + p_t q_t x_{it} \tag{2}$$

Where w_t stands for the average real wage, q_t is the average price of input, and p_t is the overall price level. Firm I will pay off the loan principal $loan_{it}$ and interest $i_t^l loan_{it}$ at the end of the period after the products are sold. Therefore, the total cost of the firm includes staff wages $p_t w_t l_{it}$, cost of material input $p_t q_t x_{it}$, and the interest of the external fund $i_t^l loan_{it}$. Under production function (1) and liquidity constraint (2), according to Chowdhury et al. (2006), we can derive from the cost minimization problem:

$$R_t^l w_t = mc_{it}(1-\alpha)a_t l_{it}^{-\alpha} x_{it}^{\alpha} \tag{3}$$

$$R_t^l q_t = mc_{it}\alpha a_t l_{it}^{1-\alpha} x_{it}^{\alpha-1} \tag{4}$$

Where $R_t^l \equiv 1 + i_t^l$ is the total rate of return on loan. If we define the percentage of labor income to intermediate product as $s_{it} \equiv w_t l_{it} / y_i$, then we can get the actual cost based on formula (3):

$$mc_{it} = R_t^l s_{it} / (1-\alpha) \tag{5}$$

The production function of the final product is:

$$y_t = \left[\int_0^1 (y_{it})^{(\theta-1)/\theta} di\right]^{\theta/(\theta-1)} \tag{6}$$

Where y_t is the final product, y_{it} is the intermediate product produced by No. i intermediate product firm, θ ($\theta > 1$) is time-varying elasticity of substitution among different intermediate products, and its reciprocal is the price elasticity of demand of the intermediate firm.

Then, the final product firm maximizes its profit:

$$Max: f(y_{it}) = y_t p_t - \int_0^1 p_{it} y_{it} di$$

Where p_{it} is the price of the intermediate product i. Then, the demand of each intermediate product:

$$y_{it} = \left(\frac{P_i}{P_t}\right)^{-\theta} y_t \text{ , } i \in [0,1] \tag{7}$$

According to the condition that the profit of the final product firm is zero in a perfectly competitive market, we derive the determination rule of the total price of the final product as:

$$P_t = \left[\int_0^1 (P_{it})^{1-\theta} di\right]^{1/(1-\theta)} \tag{8}$$

With respect to price stickiness, assume $(1 - \phi)$ is the probability of price that can be set in a specifically certain period. As far as the firms who can set the product price is concerned, their goal is to maximize the discounted total profits $E_t \sum_{s=0}^{\infty} \eta_{t,t+s} \Delta_{t+s}^{f}$, where $\Delta_{it}^{f} = (P_{it} - P_t mc_{it}) y_{it}$. In other words, these firms need to set a new product price p_{it}^{*} in each period to optimize the below problem:

$$\underset{p_{it}^{*}}{Max}: E_t \sum_{s=0}^{\infty} \phi^s \eta_{t,t+s} \left(P_{it}^{*} - P_{t+s} mc_{it+s}\right) y_{it+s}$$

$$s.t. \quad y_{it+s} = \left(\bar{\pi}^{s} P_{it}^{*}\right)^{-\theta} P_{t+s}^{\theta} y_{t+s}$$

The rest of the firms that cannot set a product price is ϕ, and they only can adjust the product price according to the average inflation $\bar{\pi} \geq 1$.

2. Household: Assume that there are many homogenous households with indefinite survival in the market and that they constitute the continuum of measure unity with measure one. The target utility function of representative households is:

$$E_t \sum_{s=0}^{\infty} \beta^s \left[\frac{c_t^{1-\sigma}}{1-\sigma} - \frac{l_t^{1-\sigma_1}}{1-\sigma_1} \right], \ \sigma>0,\ \sigma_1<0 \tag{9}$$

Where c_t is consumption, l_t is labor, and β is subjective discount rate. Assume that a household has cash M_t, government bond B_t, and exogenously given materials at the beginning of period t. In addition, assume that the bank deposit in each period is D_t. Then, the liquidity constraint of the household is:

$$P_t c_t \leq M_t - D_t + P_t w_t l_{it} + P_t q_t x_{it} + P_t \tau_t \tag{10}$$

Where τ_t is the lump-sum transfer of government. Similar to Chowdhury et al. (2006), the household in this model owns the firm and the financial intermediary, that is, the firm and bank are owned by the household. Then, the budget constraint of the household is:

$$M_{t+1} + D_t + B_{t+1} + p_t c_t \leq M_t + (1 + i_t^d) D_t + (1 + i_t) B_t + P_t w_t l_t + P_t q_t x_t + P_t \tau_t + \Delta_t^f + \Delta_t^b \tag{11}$$

Where i_t and i_t^d are bond rate and deposit rate, respectively. Solving the formula (9)~(11) and the optimal problem of non-Ponzi conditions regarding M_0 and B_0, we get the below first-order condition:

$$c_t^{-\sigma} = \lambda_t + \lambda_t^c \tag{12}$$

$$(\lambda_t + \lambda_t^c) w_t = l_t^{\sigma_1} \tag{13}$$

$$\frac{1}{\beta} \lambda_t = E_t \left[\frac{1}{\pi_{t+1}} (\lambda_{t+1} + \lambda_{t+1}^c) \right] \tag{14}$$

$$\frac{1}{\beta} \lambda_t = E_t \left[\frac{1 + i_{t+1}}{\pi_{t+1}} \lambda_{t+1} \right] \tag{15}$$

$$i_t^d \lambda_t = \lambda_c \tag{16}$$

From the binding formula (11), we get:

$$\eta_t\left(m_t - d_t + w_t l_t + \tau_t - c_t\right) = 0 \tag{17}$$

And the transversality condition:

$$\lim_{i\to\infty} E_t \lambda_{t+i} \beta^{t+i} \left(B_{t+i} + M_{t+i}\right)/P_{t+i} = 0 \tag{18}$$

Among the captioned conditions above, the discount factor $\eta_t \geq 0$, and $\left(m_t - d_t + w_t l_t + \tau_t - c_t\right) \geq 0$, where λ_t is the shadow price of wealth and λ_c is Lagrange multiplier of budget constraint (11). Then, the relationship between the consumption in period t+s and in period t for household can be connected by a stochastic discount factor:

$$\eta_{t,t+s} = \beta^s \frac{\lambda_{t+s} + \lambda_{t+s}^c}{\pi_{t+s}\left(\lambda_t + \lambda_t^c\right)} \tag{19}$$

3. Government: The government is divided into the Central Bank and the Bureau of Finance. The Central Bank is responsible for setting a nominal interest rate $R_t = 1 + i_t$ and the adjustment rule of the interest rate is:

$$\hat{R}_t = \rho_\pi \hat{\pi}_t + \varepsilon_t \tag{20}$$

Where ε_t is white noise. The Bureau of Finance needs to maintain the government's budgetary equilibrium:

$$M_{t+1} - M_t + B_{t+1} - R_t B_t = P_t \tau_t \tag{21}$$

In the meantime, the supply of government bonds is zero. To ensure the solvency of government, the below formula must be met:

$$\lim_{i\to\infty}\left(B_{t+i} + M_{t+i}\right)\prod_{\upsilon=1}^{i}\left(1 + i_{t+\upsilon}\right)^{-1} = 0 \tag{22}$$

3.2 Empirical model

Based on the above models, we can derive the aggregate price formula:

$$P_t = \left[(1-\phi)(P^*)^{1-\theta} + \phi\bar{\pi}P_{t-1}^{1-\theta}\right]^{1/(1-\theta)} \quad (23)$$

According to formula (23) and the above-mentioned log-linear equations of first-order condition, we can get:

$$\pi_t = \gamma_f E_t \pi_{t+1} + \chi m \quad (24)$$

In formula (24), the coefficient $\gamma_f = \beta$, $\chi = (1-\phi)(1-\beta\phi)\xi/\phi$, where $\xi \equiv (1-\alpha)/\{1+\alpha(\theta-1)\}$. From the log-linear formula (5), we can get:

$$\hat{mc} = \hat{R}_t^l + \hat{s}_t \quad (25)$$

In this model, the bank in the financial market will take savings D_t from household, and then make a loan $Z_t = \sum_{i=0}^{1} Z_i$. The nominal interest rate is i_t^l, and the principal with accrued interest, $(1+i_t)D_t$, will be paid off at the end of a period, which is also $R_t D_t$. Assume that the incurred expense of these financial institutions (banks) can be measured by the fixed cost per unit loan, and define the value $\kappa \geq 0$. In addition, assume a continuously-differentiable function $\Psi(R_t)$ with domain $(0,1)$ to represent the loan default rate. The higher the interest rate R_t, the higher the loan default rate. Thus, the profit of the bank is $\Delta_t^b = R_t^l[1-\Psi(R_t)]Z_t - R_t D_t - \kappa Z_t$, and, under the equilibrium condition $Z_t = D_t$, solving the formula based on the profit maximization, deriving the first-order condition, and implementing log-linearization, we get:

$$\hat{R}_t^l = (1+\Psi_R)\hat{R}_t \quad (26)$$

Where $\Psi_R = \Psi_1 - \Psi_2 = \bar{\Psi}'\bar{R}/(1-\bar{\Psi}) - \kappa/(\kappa+\bar{R})$, and Ψ_R could be either positive or negative, depending on the relative level of financial market friction and the bank's administrative management fee (Chowdhury et al., 2006). Substituting formulas (25) and (26) into equation (24), we get:

$$\hat{\pi}_t = \gamma_f E_t \hat{\pi}_{t+1} + \chi\hat{s}_t + \chi(1+\Psi_R)\hat{R}_t \quad (27)$$

This is the empirical cost channel test model, which is also called the interest-rate-augmented Phillips curve. In the above formula (27), χ measures the intensity of the traditional demand-side channel, while $\chi(1 + \psi_R)$ measures the size of the supply-side cost channel. This empirical model is applied very widely in foreign and domestic literatures on cost channels (Ravenna & Walsh, 2006; Tillmann, 2009; Hai Jiang and Zhuzhen Chu, 2011).

4 Empirical analysis

4.1 Empirical test on cost channel

4.1.1 Data selection and processing

This paper uses quarterly data to test the cost channel in China. The quarterly data of macroeconomic variables have been established formally only since 1990s, and monetary policy only began to play an important role in mid-1990s. In the meantime, the reform of the tax-sharing system implemented in 1994 had a great impact on the Chinese economy. Additionally, the Chinese central bank has launched some innovative monetary policy adjustment tools and has frequently carried out the operations of mortgage supplementary loan (PSL) and medium-term lending facility (MLF). Furthermore, the unexpected stock crash in 2015 forced the Chinese government to strengthen market intervention. Objectively speaking, the above-mentioned factors distorted the transmission channel of monetary policy. Therefore, this paper chooses the sample period from the first quarter of 1995 to the fourth quarter of 2014. The data come from the CEIC database and the China Statistical Yearbook. The empirical model includes three variables: inflation, percentage of labor income to intermediate product, and financing rate. We choose seven observable variables to measure and calculate the values of the above three variables accordingly; the observable variables include Consumer Price Index (CPI), Retail Price Index (RPI), Total Wage Income (WI), Gross Domestic Product (GDP) and the financing rates offered by the bank, including loan interest rates less than six months and seven-day interbank rate.

To obtain the volatility series, the data need to be processed; the method used is similar to that of Hai Jiang and Zhuzhen Chu (2011). First, WI is divided by GDP to obtain the time series of the percentage of labor income to intermediate product. Second, natural logarithms are taken on CPI, RPI, percentage of labor income, and the two types of financing rates offered by the bank. Third, seasonal adjustment is made on Log (CPI) and Log (RPI). Finally, the deviation value of each series is calculated from steady state. Following the above steps, we obtain the volatility series. This paper uses the average value as the estimation of the steady-state value by referring to Gali & Gertler (1999). In addition, by referring to Ravenna & Walsh (2006) and Tillmann (2009), the set of instrumental variables includes four-order lags of CPI and RPI, percentage of labor income, loan interest rate less than six months, and output gap. The output gap can be derived by the HP filtering processing of GDP.

We need to point out that most of the domestic scholars use CPI as the proxy of inflation based on the classical practice. However, this paper believes that RPI is better than CPI as the proxy of inflation, because the cost channel is based on the supply-side channel of a firm's production cost. According to the transmission process of the cost channel, the firm's production and product price will be the most directly affected, while RPI has a closer relationship with these two factors. Thus, this paper will use RPI as the proxy of inflation.

4.1.2 Statistical analysis and stationarity test

The processed time-series variables are either negative or positive, but, generally, the volatility is relatively low, with the minimum standard deviation 0.0032 and maximum standard deviation 0.0507, and it seems that the data are stable. To confirm that the data meet the stable requirement of time series from the quantitative point of view, we carry out the Augmented-Dicky–Fuller (ADF) test; the results are in Table 1.

Table 1. Stability test of main variables

Variables	ADF Test Value	Test Type	Threshold Value			Conclusion
			1%	5%	10%	
cpi***	-3.635	(0,0,1)	-3.544	-2.909	-2.590	Stable
rpi***	-4.243	(0,0,1)				Stable
s***	-3.575	(0,0,0)	-3.542	-2.908	-2.589	Stable

Note: ***, **, and * indicate statistical significance at the 99%, 95%, and 90% levels, respectively. ADF is to test the stability of time series, and the null hypothesis is that the variable is subject to the unit root process. (c,t,p) is the setting of model, and c, t, and p represent constant term, trend term, and lag order, respectively. The lag order here is the same as that in Hai Jiang and Zhuzhen Chu (2011).

4.1.3 GMM estimation

This paper will use the GMM method to estimate parameters, defining G_{t-1} as the instrumental variable group vector. According to Tillmann (2009) and Ravenna & Walsh (2006), among others, the orthogonality conditions of empirical equations can be expressed as below:

$$E_t\left\{\left(\hat{\pi}_t - \gamma_f \hat{\pi}_{t+1} - \chi \hat{s}_t - \chi\left(1 + \Psi_R\right)\hat{R}_t\right)G_{t-1}\right\} = 0 \qquad (28)$$

According to the model settings, we know that the coefficient χ in the empirical model stands for the size of the traditional demand-side channel, while $\chi(1 + \psi_R)$ stands for the size of the supply-side cost channel. Therefore, the cost channel does not exist independently, and its transmission effect will be affected by the demand-side channel. To obtain the pure cost channel effect, excluding the demand-side channel, this paper derives $\chi(1 + \psi_R)$, under the condition that both χ and $\chi(1 + \psi_R)$ are significant, to dig out more information from the limited data. However, it needs to be noted that this kind of pure cost channel effect is not a real reflection of the cost channel.

The empirical results are shown in Table 2. According to Table 2, all the coefficients are positive, and the J- statistics' values show that the overidentifying assumption cannot be rejected. In other words, the instrumental variable group is effective.

Table 2. GMM estimation results based on RPI

Financing Rate	γ_f	χ	$\chi(1+\psi_R)$	$1+\psi_R$	J- statistics
Loan Interest Rate Less Than Six Months	0.95^{***} (0.03)	0.03^{**} (0.01)	0.42^{***} (0.05)	13.91	20.67 (0.24)
Seven-day Interbank Rate	0.98^{***} (0.04)	0.02 (0.01)	0.17^{***} (0.03)	—	16.75 (0.47)

Note: ***, **, and * indicate statistical significance at the 99%, 95%, and 90% levels, respectively. Standard errors are in parenthesis from column 2 to column 4. The null hypothesis of J-statistics test is that overidentifying restrictions exist. J- statistics' values are in parenthesis in column 5.

Table 3. GMM estimation results based on CPI

Financing Rate	γ_f	χ	$\chi(1+\psi_R)$	$1+\psi_R$	J- statistics
Loan Interest Rate Less Than Six Months	0.59^{***} (0.10)	-0.002 (0.00)	0.038^{*} (0.02)	—	33.19 (0.10)
Seven-day Interbank Rate	0.85^{***} (0.15)	-0.003 (0.00)	0.011 (0.01)	—	21.89 (0.19)

Note: ***, **, and * indicate statistical significance at the 99%, 95%, and 90% levels, respectively. Standard errors are in parenthesis from column 2 to column 4. J- statistics' values are in parenthesis in column 5.

According to the empirical results, we find: First, the cost channel does exist, and the coefficient $\chi(1+\psi_R)$ is significantly positive at the 99% level. Second, the traditional demand-side channel is significantly positive at the 95% level, but the coefficient χ is much smaller than $\chi(1+\psi_R)$. Third, the value of the pure cost channel effect is as much as 13.91 after calculation. Compared to other research, this paper finds that the cost channel effect is much more significant. The reason for this may be, on the one hand, as Tillmann (2008) pointed out, if the explanatory variables of the regression equation do not include the lagged term of inflation, this will increase the influence weight of the interest rate in the current period and further amplify the cost channel effect. On the other hand, the friction of the financial market will result in the firm's working capital being hard to keep stable and its volatility being large and, furthermore, increase the impact of the volatility of the interest rate on the firm's costs (Tillmann , 2009). In fact, many researchers have already demonstrated that the unique financial resource allocation model in China makes it difficult for non-state-owned firms to compete with state-owned firms in financial resources. Financial segmentation might be the one of the most important factors increasing both the significance and the degree of the cost channel.

To test the stability of the above results, we use the loan interest rate less than six months and seven-day Interbank Rate, respectively, as the firm's financing rate to conduct regression analysis. From Table 2, we can see that the conclusions are the same, but the demand-side channel is not significant when we use the seven-day Interbank Rate as the firm's financing rate. Thus, we do not calculate the value of the pure cost channel effect at this time.

Additionally, RPI has a closer and more direct relationship with the cost channel than does CPI, as mentioned above. Therefore, we list the regression results by use of CPI as the proxy of inflation in Table 3. From Table 3, we can observe that the significance of the cost channel decreases dramatically and that the traditional demand-side channel is not significant, with even the signs of coefficients becoming negative. These results are in line with our expectations.

As inflation will be influenced by a firm's financing rate under the cost channel, the question arises as to whether the cost channel will impact the dynamic behavior of inflation. To answer this question, we use the first-order difference of RPI as the dependent variable to investigate whether the cost channel effect exists under a different financing rate. The results are listed in Table 4. It is easy to see that both the traditional channel and the cost channel are either not significant or less significant, and the sign of the coefficient is contrary to the theoretical assumption. The results are similar to those of Hai Jiang and Zhuzhen Chu (2011). Neither the traditional channel nor the cost channel describe the dynamic behavior of inflation, and the existence of the cost channel could not be tested by taking advantage of the first order difference of inflation. A possible explanation of why the traditional channel and cost channel could not explain the dynamic change of inflation and are mainly the channels of monetary policy transmission may be because the dynamic change of inflation in the sample period is subject to random distribution, while the traditional channel and the cost channel are highly positively correlated.

Table 4. GMM estimation results based on ΔRPI

Financing Rate	γ_f	χ	$\chi(1+\psi_R)$	$1+\psi_R$	J- statistics
Loan Interest Rate Less Than Six Months	0.42*** (0.14)	-0.023 (0.02)	-0.166* (0.097)	—	24.18 (0.11)
Seven-day Interbank Rate	0.37*** (0.14)	0.021 (0.01)	-0.108 (0.042)	—	18.71 (0.35)

Note: ***, **, and * indicate statistical significance at the 99%, 95%, and 90% levels, respectively. Standard errors are in parenthesis from column 2 to column 4. J- statistics' values are in parenthesis in column 5.

4.1.4 Rolling-Window GMM estimation

This paper conducts continually rolling estimates of the coefficients of a regression equation based on a window width of 12 quarters. The sample periods total 80 quarters. The coefficient of the first-phase cost channel is the estimation value of a regression equation based on data from the first quarter of 1995 to the fourth quarter of 1997, with a total of 12 quarters, and the coefficient of the second-phase cost channel is the estimation value of a regression equation based on the data from the second quarter of 1995 to the first quarter of 1998, with a total of 12 quarters; the remainder will be carried out in the same manner. The window width can be set freely; however, if the window width is too long, the estimation values of coefficients will be less, while, if the window width is too short, the estimation values of coefficients will be insufficiently robust. Considering the above two factors, we choose a window width of 12 quarters and obtain 69 estimation values of cost channel coefficients. As the distribution characteristics of the estimation results of coefficients are basically similar, we use the window width of 12 quarters to study the time-varying nature of the cost channel.

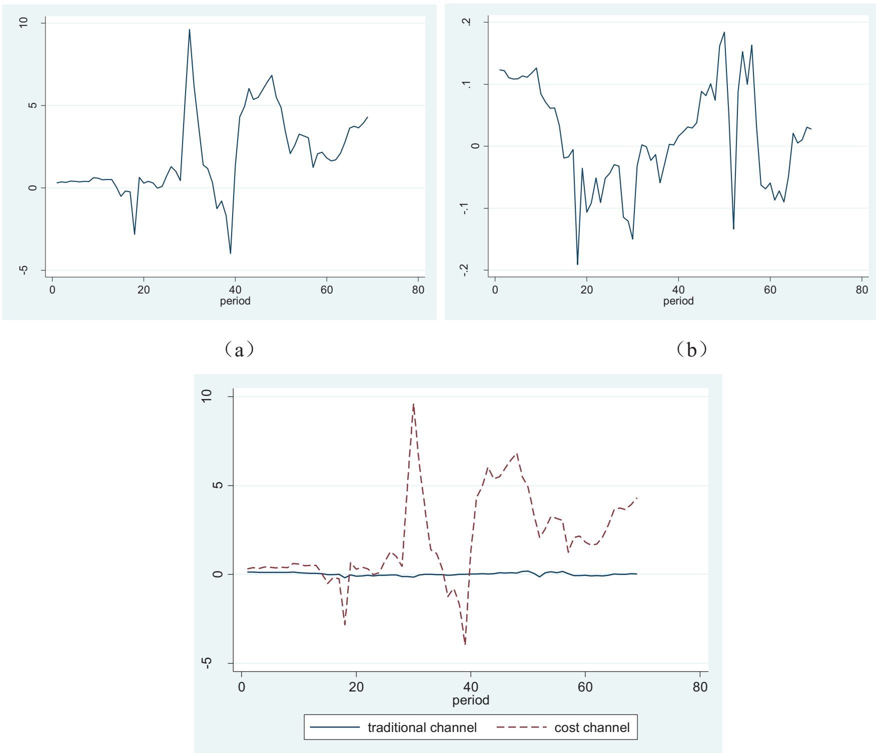
Figures 1 (a) and (b), respectively, exhibit the changes of the coefficients' estimates of the cost channel and the traditional channel with the shift of window width, and we can observe that these two estimated values fluctuate between high and low with the shift of time. In particular, after arriving at its peak value of 9.621, the coefficient of the cost channel decreases until the 40th period. This period of time is from 2002 to 2005. During this period, the proactive fiscal policy implemented by the Chinese government in 1998 achieved significant success. Under the guidance of eliminating the barriers in systems, promoting private investment growth, and ensuring that all the fields that state-owned enterprises and foreign investment can enter are open to private sectors, the scale of corporate bond financing increased sharply, by 447.68%, reaching RMB 201 billion.[2] Subsequently, the Chinese government began to implement prudent fiscal policy. This process exactly reflected the theoretical expectation that financial friction has a positive relationship with the cost channel effect. At the beginning of 2007, the coefficient of the cost channel began to decrease with volatility, due to the significant achievements of financial liberalization, especially the RMB interest rate and exchange rate forming system reform, in addition to the shareholding system reform and the initial public offering of state-owned commercial banks. During 2007–2012, the scale of corporate bond financing increased sharply, by 887.35%, reaching RMB 2255.1 billion. Therefore, the intensity of the cost channel is closely related with the marketization reform of the financial market.

Figure 1 (c) shows the coefficient estimates of both the traditional channel and the cost channel. From Figure 1, we observe that the traditional channel fluctuates around its mean value of 0.123, with a standard deviation of 0.085, while the volatility of the cost channel is very high, with a standard deviation of 2.482, and most of its coefficient estimates show upward bias, with a mean value of 1.899. These results show: (1) The volatility of the cost channel has nothing to do with the setting of the empirical model, i.e., the New Keynesian Philips Curve, because the cost channel is stable in this model. (2) The cost channel exists in China, but it is not totally stable and presents a very strong time-varying characteristic, which is in line with the findings of Barth & Ramey (2001). The results of Figure 1 are the rolling-window estimates based on using a loan interest rate less than six months as the firm's finance rate.[3]

[2] Data from the database of National Bureau of Statistics of China. The same below.

[3] We also use the loan interest rate from six to twelve months and seven-day interbank rate to conduct rolling-window estimations, and the results are same as the results obtained by using the loan interest rate of less than six months as the firm's finance rate.

Figure 1. Comparison between time-varying characteristics of cost channel (r_6months) and traditional channel



(a) (b)

(c)

4.2 Empirical test on the impact of cost channel on inflation

4.2.1 Establishment of TVP–VAR model

We further set up a time-varying parameter VAR (TVP–VAR) to analyze the existence of the cost channel and its impact on inflation. The TVP–VAR model assumes that the parameters to be estimated are subject to the first-order random walk process and can capture the time-varying characteristics of the lag structure of the model, in addition to other possible non-linearity characteristics. We refer to Nakajima (2011) to set up the model.

First, a classical VAR model is introduced:

$$Ay_t = F_1 y_{t-1} + \ldots + F_s y_{t-s} + u_t, \quad t = s+1, \cdots, n \tag{29}$$

Where y_t is $k \times 1$ dimension vector, A and $F_1, \ldots F_s$ are $k \times k$ dimension coefficient matrix, and μ_t is $k \times 1$ dimension structural shock term. We assume $\mu_t \sim N(0, \Sigma\Sigma)$, where:

$$\Sigma = \begin{bmatrix} \sigma_1 & 0 & \ldots & 0 \\ 0 & \ldots & & \\ \ldots & & & 0 \\ 0 & \ldots & 0 & \sigma_k \end{bmatrix}, \qquad A = \begin{bmatrix} 1 & 0 & \ldots & 0 \\ a_{21} & \ldots & & \\ \ldots & & & 0 \\ a_{k1} & \ldots & a_{k,k-1} & 1 \end{bmatrix}$$

Model (29) can be simplified, as below:

$$y_t = B_1 y_{t-1} + \cdots + B_s y_{t-s} + A^{-1}\Sigma\varepsilon_t \ , \varepsilon_t \sim N(0, I_k) \tag{30}$$

The parameters of the above SVAR model do not have time-varying characteristics. Then, we extend the model parameters dynamically and stack the elements in B to obtain $k^2s \times 1$ dimension vector β. Defining $X_t = I_k \otimes (y'_{t-1}, \ldots, y'_{t-s})$, where $\otimes$ stands for Kronecker product, the model can be simplified as below:

$$y_t = X_t \beta + A^{-1}\Sigma\varepsilon_t \tag{31}$$

The parameters of the above SVAR model do not have time-varying characteristics. If all the coefficients and parameters are allowed to have time-varying characteristics, the above VAR model can be extended to the TVP–VAR model:

$$y_t = X_t \beta_t + A_t^{-1}\Sigma_t \varepsilon_t, t = s+1, \ldots, n \tag{32}$$

Where coefficient β_t, parameter A_t, and the covariance matrix Σ_t, fluctuating with the shift of time, have time-varying characteristics. To reduce the model parameters to be estimated, the elements that are not either 0 or 1 in the lower triangular matrix A_t are stacked to a column vector. Then, we obtain $a_t=(a_{21}, a_{31}, a_{32}, a_{41},\ldots, a_{k,k-1})$. Let $h_t=(h_{1t},\ldots, h_{kt})$, where $h_{it} = \log\sigma_{it}^2, i=1,\ldots,k; t=s+1, \quad ,n$. Assume that the parameters of model (32) are subject to the random walk process:

$$\begin{array}{l}\beta_{t+1}=\beta_t+\mu_{\beta t},\\ a_{t+1}=a_t+\mu_{at},\\ h_{t+1}=h_t+\mu_{ht},\end{array}\quad,\quad \begin{pmatrix}\varepsilon_t\\ \mu_{\beta t}\\ \mu_{at}\\ \mu_{ht}\end{pmatrix}\sim N\left(0,\begin{pmatrix}I&0&0&0\\0&\Sigma_\beta&0&0\\0&0&\Sigma_a&0\\0&0&0&\Sigma_h\end{pmatrix}\right), t=s+1,\ldots,n \tag{33}$$

Where $\beta_{s+1}\sim N\left(\mu_{\beta_0}, \ \Sigma_{\beta_0}\right), a_{s+1}\sim N\left(\mu_{a_0}, \ \Sigma_{a_0}\right), h_{s+1}\sim N\left(\mu_{h_0}, \ \Sigma_{h_0}\right)$. Both Σ_a and Σ_h are diagonal matrices.

4.2.2 Data selection and parameters estimation

We choose RPI as the indicator of cost channel and two different interest rates as the explanatory variables to set up a time-varying parameter vector autoregressive model, in which the time-varying coefficients that measure the cost channel come from the results of the above rolling-window GMM estimation, totaling 69 periods. Regarding the interest rate and inflation data, the interest rate used in this paper is the interest rate gap after HP filtering processing, and the inflation is its logarithmic difference value. Then, we take the rolling-window average value of quarterly data according to window width (12 quarters) and obtain 69 periods' data.[4]

Referring to the method of assigning the initial value from Nakajima (2011), we assume $\mu_{\beta_0}=\mu_{a_0}=\mu_{h_0}=0$ and $\Sigma_{\beta_0}=\Sigma_{a_0}=\Sigma_{h_0}=10\times I$. We decide that the optimal lagged order is 2 based on Marginal Likelihood Function. We assume that the ith diagonal line of covariance matrix is subject to Gamma distribution: $\left(\Sigma_\beta\right)_i^{-2}\sim Ga(40,0.02), \left(\Sigma_a\right)_i^{-2}\sim Ga(4,0.02), \left(\Sigma_h\right)_i^{-2}\sim Ga(4,0.02)$. We use the MCMC method to simulate 10000 times; the results are listed in Table 5.

In Table 5, the variables in Model I include RPI, Loan Interest Rate

[4] Because the data sample period of seven-day interbank rate start from the first quarter of 1996, only the data from 5th period to 69th period are obtained after transformation method.

Less Than Six Months, and the coefficients of the cost channel, estimated by rolling-window GMM based on Loan Interest Rate Less Than Six Months. The variables in Model II include RPI, Seven-day Interbank Rate, and the coefficients of the cost channel estimated by rolling-window GMM based on the Seven-day Interbank Rate. According to Table 5, from the angle of convergence, the Geweke values of all parameters do not exceed a threshold value of 1.96 at the level of 95%, indicating that the null assumption of convergence to posterior distribution cannot be rejected. On the other hand, the invalid influence factors of all parameter estimates are very small, and the maximal value is 65.88, indicating that we can get at least 10000/65.88≈152 uncorrelated samples, which is enough for posterior inference.

Table 5. Estimation results of TVP-VAR model

Parameters	Model I				Model II			
	Mean value	Standard Deviation	Geweke Diagnostic Value	Invalid Influence Factor	Mean value	Standard Deviation	Geweke Diagnostic Value	Invalid Influence Factor
$(\Sigma_\beta)_1$	0.0022	0.0000	0.682	1.09	0.0023	0.0003	0.094	5.10
$(\Sigma_\beta)_2$	0.0022	0.0000	0.113	0.81	0.0023	0.0003	0.187	1.96
$(\Sigma_\alpha)_1$	0.0157	0.3209	0.252	6.85	0.0059	0.0057	0.828	32.57
$(\Sigma_\alpha)_2$	0.0057	0.0017	0.265	20.92	0.0056	0.0016	0.293	21.44
$(\Sigma_h)_1$	0.0124	0.0304	0.131	53.44	0.0061	0.0055	0.799	65.88
$(\Sigma_h)_2$	0.0084	0.0161	0.032	58.70	0.0059	0.0051	0.485	33.41

4.2.3 Existence of cost channel and impulse response analysis on its impact on inflation

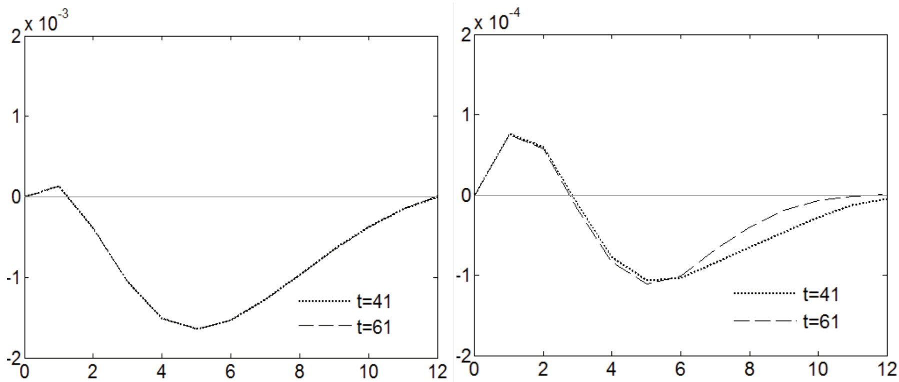
To study the existence of the cost channel and its impact on RPI, we choose the 41st period and the 61st period as the representative observation points to conduct impulse response analysis. The 41st period and the 61st period, respectively, correspond to the two-round price rising process in 2007 and during 2010 to the first half year of 2011, in addition to the rising process of cost channel coefficients.

Figures 2(a) and (b) show the impulse response of a Loan Interest

Rate Less Than Six Months and the Seven-day Interbank Rate on RPI at different points in time. From Figure 2, we can see that, irrespective of the interest rate indicator, the impulse effect of the interest rate on RPI at the points of time t=41and t=61 is basically the same, because the impulse response charts of Figures 2(a) and (b) at different points of time are almost coincident. Most importantly, irrespective of the interest rate indicator, the response of RPI to the impulse effect of the interest rate is positive in the first period, deceases rapidly to negative, and gradually converges after reaching the minimum value at the fifth period. These findings are the same as those of Hai Jiang and Zhuzhen Chu (2011), indicating that the tight monetary policy will lead to the rise of RPI in the short run, and, thus, further proving the existence of the cost channel.

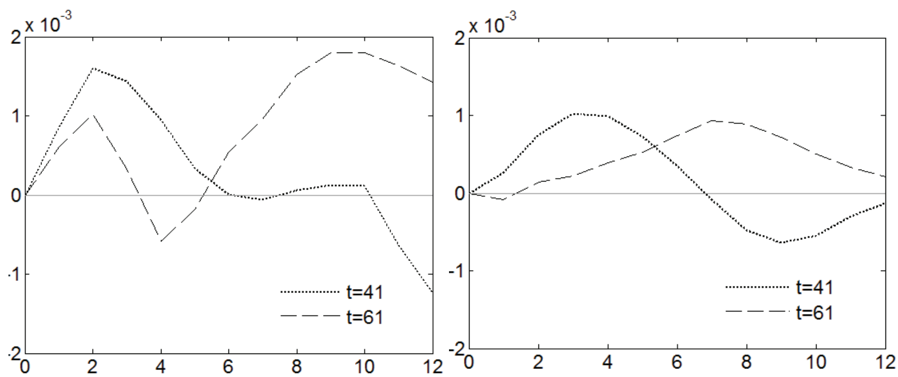
Furthermore, we investigate the response of RPI to the impulse effect of the cost channel at different points of time. Figures 3(a) and (b) exhibit the response of RPI to the impulse of cost channel coefficients estimated by rolling-window estimation based on Loan Interest Rate Less Than Six Months and Seven-day Interbank Rate. Figure 3(a) shows that, when t=41 and t=61, the response of RPI to one positive impulse of the cost channel (based on Loan Interest Rate Less Than Six Months) is positive at the beginning and reaches a maximum value at the second period. When t=41, the impulse response of the cost channel on RPI is positive until the sixth period. When t=61, the impulse response of cost channel on RPI becomes negative from the third period, turns to positive at the fifth period, and presents the effect of a longer lagged period. Figure 3(b) shows that, when t=41, the response of RPI to one positive impulse of the cost channel (based on Seven-day Interbank Rate) is positive at the beginning, reaches a maximum value at the third period, and remains positive until the seventh period. When t=61, the impulse response of the cost channel on RPI is more flat and persistent.

Figure 2. Response of RPI to impulse of interest rate



(a) ε(r-6months)↑→RPI (b) ε(r-Libor7days)↑→RPI

Figure 3. Response of RPI to impulse of cost channel



(a)ε(CC-6months)↑→RPI (b)ε(CC-Libor7days)↑→RPI

Note: CC stands for cost channel.

Based on the above analysis, the cost channel played a very significant role in driving the two-round rising of inflation in 2007 and from 2010 to the first half year of 2011. During the rising process of inflation in 2007, the pulling effect of the cost channel on inflation had a short-term significant impact, while it had a persistent impact from 2010 to the first half year of 2011.

5 Concluding remarks

This paper derives the New Keynesian Phillips curve under a general equilibrium model, and, furthermore, based on existing literature, derives an empirical model for testing the cost channel. Compared to domestic literature on the cost channel in China, this paper pays much more attention to broadening the data sample for researching the cost channel, in order to achieve more robust conclusions. In addition, this paper analyzes the existence of the cost channel and the response of RPI to the impulse effect of the cost channel.

We find that: First, the cost channel exists significantly in China, although this is related to the fact that our empirical model does not include the lagged term of inflation, and the financial market friction is a very important real factor that results in a cost channel under the China-style allocation model of financial resources. Therefore, the conclusion is robust based on different financing rates. Second, both the traditional demand-side channel and the supply-side cost channel fail to describe dynamic behavior of inflation. Third, the traditional channel is more stable, while the cost channel has very significant time-varying characteristics. Finally, in the process of two-round price rises in 2007 and from 2010 to the first half year of 2011, the tight monetary policy resulted in the rise of inflation, and the cost channel had a significant impact on the price rises.

According to the conclusions, we suggest that monetary policy makers need to pay attention to three aspects: First, when the economy is overheated, the policy makers should be careful to adopt tight monetary policy to control inflation. In some situations, tight monetary policy might be invalid, because it could be offset by a supply-side effect, and inflation will worsen when the overall dependence of firms on external funds is very large. Second, when both the scale of the economy and credit demand continue to expand, the policy makers should consider not only the demand-side influence but also the supply-side influence when undertaking tight monetary policy. In the Chinese non-marketization financial system, in particular, the commercial banks adopt a double standard to allocate credit capital. This kind of non-marketization financial system increases the financial market friction, leads to cost channel instability and the uncertainty of macroeconomic regulation and control in China, and, thus, increases the difficulty of macroeconomic regulation and control. Finally, the time-varying characteristics indicate that the policy makers should conduct dynamic and deep research into the cost channel of monetary policy during the process of the adjustment and transformation of economic structure and the reform of the financial system.

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