Cost Channel and Optimal Monetary Policy: Financial Frictions and Foreign Shocks

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ABSTRACT

This paper deepens both theoretically and empirically the cost channel of monetary policy, which affects inflation via marginal cost inherent in working capital of firms. This setup incorporating financial frictions is extended to a small open economy such as Taiwan, an emerging market with a bank-based financing system. Utilizing Taiwan's data over 1982:Q1-2005:Q4, the GMM estimation suggests that the cost-channel effect on inflation dominates the standard demand-side effect and amplifies under the combined impacts from both financial frictions and small openness. Besides, the calibrations for discretionary and commitment policies indicate that the tradeoff between inflation and output gap stabilizations under the cost channel also applies but appears greater, since the optimizing central banker faces more destabilizing factors that govern both domestic and international financial markets.

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1. INTRODUCTION

As many emerging market economies today, Taiwan still keeps a bank-based financial system despite rapid growth in local financial markets. The majority of firms, mainly small and medium sized, hinge exclusively on bank lending for both short-term and long-term financing. For example, the annual statistics released by Taiwan's central bank indicate that bank lending expressed in stock terms constantly represents two-fifth of total debt for firms whereas commercial papers account for only 5% over the period between 1982 and 2005. This trend opens up the possibilities of studying the cost channel with financial frictions and its implications for monetary policy and inflation in Taiwan, against other emerging market economies where firms' financing relies more on capital markets.

Thus, the purpose of this paper attempts to deepen both theoretically and empirically the cost channel with analysis that incorporates both financial frictions and foreign shocks and derive implications for optimal monetary policy in Taiwan. The rationale behind the cost channel, as pointed out in Blinder (1987), Christiano and Eichenbaum (1992), and Christiano et al. (1997), is related with a liquidity effect of the bank lending rate on working capital of firms who usually borrow from financial intermediaries to pay for wages before selling their products. The change in the interest rate driven by a monetary shock therefore affects directly firms' marginal cost and output. Through the firm's pricing behavior, the price level adjusts in the opposite direction to the level of output, which contrasts with traditional demand-side transmission mechanisms of monetary policy.

In extant literature, the interest rate channel and the extended exchange rate channel provides standard explanation of how domestic and foreign shocks affect the macroeconomy, whereas the credit channel stresses their impacts on bank-dependent sectors under imperfection in the financial market. These demand-side channels state that, at least in the short run, monetary policy leads to the change in output which moves in the same direction as the price level but in the opposite direction to the interest rate and the exchange rate expressed as the value of the domestic currency in terms of the foreign currency.

Recent studies, such as Barth and Ramey (2002), Ravenna and Walsh (2006) and Chowdhury et al. (2006), argue that there may exist supply-side transmission mechanisms dubbed as the cost channel. Their works, however, discuss the issue in a closed economy only. Barth and Ramey (2002) indicate that the cost channel is an extension rather than a refutation to demand-side channels. It also serves to elucidate at least three stylized facts about monetary policy. The first concerns the price puzzle that observes a fall in the price level following a rise in money supply. The second involves, as mentioned by Bernanke and Gertler (1995), an amplified and persistent effect of monetary policy on output. The third relates to the real effect the policy creates. With clarification by the cost channel, the three facts that seemingly oppose to conventional wisdom appear explicable and proven to be interconnected. Contrary to other types of demand-side shocks, a monetary shock is able to change, because of an additional impact on working capital for firms, both aggregate demand and aggregate supply. On one hand, the shift in the latter generates a real effect analogous to that caused by supply-side shocks such as technological progress; on the other hand, the simultaneous movement in demand and supply leads to amplifying output growth but possibly attenuating inflation because of their offsetting effect on the price level.

Ravenna and Walsh (2006) advance the cost channel literature by estimating with the US data a forward-looking New Keynesian Phillips curve and find that inflation is directly affected by the nominal interest rate that represents a type of marginal cost for firms, suggesting the very presence of the cost channel. They also demonstrate that the cost channel alters implications for optimal monetary policy, under which stabilization in the output gap will be accompanied with fluctuations in inflation. Chowdhury et al. (2006) take into account financial market frictions that lead to a spread between the market interest rate and the bank lending rate and estimate with G7 data a hybrid New Keynesian Phillips curve. Their empirical findings substantiate the cost channel and the resulting interest rate pass-through on inflation, too.

This paper essentially refines the model of Ravenna and Walsh (2006), embedded with financial frictions specified by Chowdhury et al. (2006) and elements that characterize a small open country influenced by foreign monetary policy as modeled by Tuesta (2004) and Woodford (2003). Our extension serves to contribute new evidence on the cost channel having been explored mainly in a closed economy setting. Utilizing Taiwan’s data over the period from 1982:Q1 to 2005:Q4, the estimation results of generalized method of moments (GMM) demonstrate a stronger pass-through effect on inflation via the cost channel than via the demand-side channel. The magnitude of this effect appears even more pronounced as the combined role played by financial frictions and foreign shocks is taken into account. The issue on optimal monetary policy is also examined to appreciate whether the output-inflation tradeoff for the central bank equally applies and evaluate its significance for both discretionary and commitment policies.

The remainder of the paper is structured as follows. Section 2 presents our expanded small open economy incorporating with financial frictions and foreign shocks in the cost channel. Section 3 describes the data for empirical analysis as regards the existence and magnitude of the cost channel effect on inflation. Section 4 discusses implications for optimal monetary policy under the cost channel by theory and calibration. Section 5 draws the conclusion.

2. THE MODEL

This section succinctly presents our theoretical model extended from Ravenna and Walsh (2006) for a small open economy characterized by Tuesta (2004) and Woodford (2003) with incorporation of frictions in the financial market highlighted by Chowdhury et al. (2006). The economy is composed of the goods market, labor market, financial market, and foreign exchange market, where the representative household, firm, financial intermediary, and government interact.

2.1 Household

The household lives forever. At the beginning of period t, the agent holds money M_t carried from the previous period, receives in advance nominal wage income W_tN_t for labor supplied N_t over period t, and deposits D_t as a part of his total wealth into the domestic financial intermediary. The basket of his consumption goods C_t includes both domestic consumption C_t^H and foreign consumption C_t^F, and his preferences are characterized by the well-defined utility function $\mathrm{E}_t \sum_{t=0}^{\infty} \beta^t \left[C_t^{1-\sigma} \big/ (1-\sigma) - \rho N_t^{1+\eta} \big/ (1+\eta) \right]$. At the end of period t, the household receives the dividend Π_t from ownerships of both the firm and the financial intermediary, real lump-sum government transfer T_t, and deposit balance $R_t^D D_t$ from the intermediary that pays the gross deposit rate R_t^D, holding money M_{t+1} left to the next period.

The household hence faces both a cash-in-advance constraint and a budget constraint as:

$$M_t + W_t N_t - D_t \geq P_t C_t \text{, and} \tag{1}$$

$$M_t + W_t N_t - D_t + R_t^D D_t + \prod_t + P_t T_t \geq M_{t+1} + P_t C_t \text{,} \tag{2}$$

where the expenditure for composite consumption C_t is measured by the consumer price index P_t, a weighted average of P_t^H and P_t^F conditioned on purchasing power parity. Under the assumption of complete international financial markets as Tuesta (2004) and Woodford (2003), uncovered interest parity can also be derived from the household's intertemporal optimization:

$$R_t^D = \mathrm{E}_t\left(\frac{e_{t+1}}{e_t}\right) R_t^{*D} \text{,} \tag{3}$$

where R_t^{*D} is the gross foreign deposit rate and e_t is the nominal exchange rate expressed as the price of foreign currency in terms of domestic currency.

2.2 Firm

The competitively monopolistic firms produce by constant-return-to-scale technology aggregate output $Y_t = A_t N_t$. Each firm sets its own price, but only part of the firms optimally adjust its price in each period *a la* the Calvo-type specification. At the beginning of period *t*, it borrows from the financial intermediary at the gross lending rate R_t^L to prepay nominal cost of labor prior to receiving revenue from selling goods, which implies a liquidity constraint linked with the working capital. All markup-based profits equal $P_t Y_t$ – $R_t^L W_t N_t$ subject to both $P_t = \left[\int P_{jt}^{(1-\theta)/\theta} dj\right]^{\theta/(1-\theta)}$ and liquidity constraint $Z_t = W_t N_t$; thus, optimization derives real marginal cost of labor φ_t^N:

$$\varphi_t^N = \frac{R_t^L w_t}{MPN_t} = R_t^L S_t^N, \tag{4}$$

where w_t and MPN_t stand respectively for the real wage and marginal product of labor. The variable S_t^N defined as $(w_t N_t)/Y_t$ represents the labor's share of income.

2.3 Financial Intermediary

The competitively financial intermediary is assumed, in period t, to take the deposit D_t from the household at the gross deposit rate R_t^D, receive money X_t (equal to $M_{t+1} - M_t$) injected from the central bank, and lend Z_t (equal to $W_t N_t$) to the firm at the gross lending rate R_t^L. Frictions in the financial market imply a time-invariant spread between R_t^L and R_t^D, a fixed management cost k for loan-making, and an increasing function $\Phi(R_t^D)$ that measures the likelihood of firm's default as the deposit rate R_t^D changes. This is rationalized by the willingness of firms to invest in risky project under asymmetric information and debt financing (Stiglitz and Weiss, 1981).

Given the intermediary's profit equal to $R_t^L[1 - \Phi(R_t^D)]Z_t - (R_t^D D_t + kZ_t)$ and balance sheet constraint $Z_t = D_t + X_t$, optimization yields:

$$R_t^L = \frac{R_t^D + k}{1 - \Phi\left(R_t^D\right)}. \tag{5}$$

It is worth noting that the non-zero default probability alters the financial intermediary's behavior of adjustment in the gross lending rate. At the end of period t the household receives the dividend Π_t equal to a fixed proportion of the sum of profits from the firm and the financial intermediary.

2.4 Government

Real government spending G_t and lump-sum transfer to the household T_t are assumed to be financed by money creation, i.e. $\left(M_{t+1} - M_t\right) \geq P_t\left(G_t + T_t\right)$.

2.5 Aggregate Resource Constraint

By setting α equal to zero for simplification of the firm's production function, the aggregate resource constraint for the small open economy is then expressed as $Y_t = \gamma_{1t}Y_t + \gamma_{2t}Y_t + (1 - \gamma_{1t} - \gamma_{2t})Y_t$, with $0 < \gamma_{1t}$, $\gamma_{2t} < 1$. The first term $\gamma_{1t}Y_t$ is consumption C_t, the second term $\gamma_{2t}Y_t$ involves financial-sector activity equal to $(1-\phi_t)\,D_t/P_t - \phi_t\,X_t/P_t$ with $\phi_t = 1 - R_t^L\Phi(R_t^D) - k$, and the final term $(1 - \gamma_{1t} - \gamma_{2t})Y_t$ refers to government spending G_t. Fiscal and financial shocks respectively change the value of γ_{1t} and γ_{2t} as these two parameters measure the ratio of consumption and financial activity to output in period t. The parameter γ_{2t} captures financial frictions reflected in ϕ_t. Furthermore, γ_{2t} is sensitive to foreign shocks given its linkage with (3) via R_t^D. This constitutes our innovation vis-à-vis Ravenna and Walsh (2006) who analyze γ_{1t} only.

3. EMPIRICAL ANALYSIS

This section develops two sets of empirical equations to assess the difference in the cost channel effect on inflation between a closed economy and an economy characterized with financial frictions and sensitive to foreign shocks.

3.1 Inflation Adjustment Equation

Galí and Gertler (1999), Galí et al. (2001), and Chowdhury et al. (2006) estimate a hybrid marginal-cost-based New Keynesian Phillips curve $\hat{\pi}_t = \gamma_b \hat{\pi}_{t-1} + \gamma_f \mathrm{E}_t \hat{\pi}_{t+1} + \tilde{\lambda} \hat{\varphi}_t^N$, where the hat over variable refers to the percentage deviation from its steady-state level. This augmented New Keynesian inflation adjustment equation states that changes in current inflation are affected not only by the weighted sum of changes in previous and expected future inflation, but also by changes in real marginal cost of labor. Log-linearization of (4) implies $\hat{\varphi}_t^N = \hat{S}_t^N + \hat{R}_t^L$, yielding the "interest-rate-augmented" New Keynesian Phillips curve dubbed by Chowdhury et al. (2006) for exploration of the cost channel with financial frictions. This curve is estimated by the GMM and expressed as follows:

$$\hat{\pi}_t = \gamma_b \hat{\pi}_{t-1} + \gamma_f \mathrm{E}_t \hat{\pi}_{t+1} + \tilde{\lambda}_1 \hat{S}_t^N + \tilde{\lambda}_2 \hat{R}_t^L + \varepsilon_t, \quad (6.1)$$

where the parameters $\tilde{\lambda}_1$ and $\tilde{\lambda}_2$ gauge the respective effect of two factors related with changes in the firm's real marginal cost of labor, $\hat{\varphi}_t^N$, on inflation.

The first effect involves $\hat{S}_t^N$, with a positive $\tilde{\lambda}_1$ that reflects the direct impact of the firm's markup pricing on inflation. Since $\hat{S}_t^N$ represents changes in the labor's share of income, $\tilde{\lambda}_1$ also captures an indirect demand-side interest rate effect of monetary policy on inflation. Monetary contraction that raises the nominal interest rate, for instance, adjusts the household's intertemporal optimization from which saving is increased at the expense of consumption, resulting therefore in a lower level of output and employment. There will be a fall in the real wage translated into the unit labor cost and thereby marginal cost for the firm, which in turn lowers inflation.

The second effect is the very cost channel of monetary policy on inflation by $\hat{R}_t^L$.

Changes in financing cost for the firm's working capital due to wage prepayment affect inflation through a direct supply-side interest rate effect because $\hat{R}_t^L$ constitutes an alternative component of the firm's marginal cost. As demonstrated in Ravenna and Walsh (2006), this impact on inflation whose magnitude is measured by $\tilde{\lambda}_2$ appears however negative. This is because endogenously changed output following a rise in $\hat{R}_t^L$ actually dominates its initial effect on inflation.

In order to compare our results with those in Ravenna and Walsh (2006), we also estimate the following equation that focuses on the net marginal cost effect on inflation:

$$\hat{\pi}_t = \gamma_b \hat{\pi}_{t-1} + \gamma_f \mathrm{E}_t \hat{\pi}_{t+1} + \tilde{\lambda}(\hat{S}_t^N + \hat{R}_t^L) + \varepsilon_t , \tag{6.2}$$

where $\tilde{\lambda}$ refers to the combined impact on inflation with changes in both the firm's core unit labor cost and its short-term financial cost for working capital to prepay the wage.

To explicitly distinguish the role of financial frictions in the cost channel, (6.1) is extended to the following:

$$\hat{\pi}_t = \gamma_b \hat{\pi}_{t-1} + \gamma_f \mathrm{E}_t \hat{\pi}_{t+1} + \tilde{\lambda}_1 \hat{S}_t^N + \tilde{\lambda}_1 \left(1 + \psi_R\right) \hat{R}_t^D + \varepsilon_t , \tag{6.3}$$

where $\psi_R = \left[\Phi'\left(R_t^D\right) R_t^D\right] \Big/ \left[1 - \Phi\left(R_t^D\right)\right] - k \Big/ \left(R_t^D + k\right)$, which captures the influence exerted by financial frictions on inflation through the cost channel, comes from log linearization of (5). It must be emphasized that the supply-side interest rate effect measured by $\tilde{\lambda}_1\left(1 + \psi_R\right)$ is distinct from the standard demand-side credit channel. Indeed, both results from financial frictions, i.e. the firm is assumed bank-dependent. But the former affects inflation directly from changes in the firm's real marginal cost of labor, $\hat{\varphi}_t^N$, by monetary shocks, while the latter influences inflation indirectly via the firm's investment decision embedded in aggregate demand.

The next step is to extend the first set of empirical equations to the second set that aims to appreciate the cost channel in an open economy subject to both financial frictions and foreign shocks. Combining log-linearized (3) and (5) into (6.3), we obtain:

$$\hat{\pi}_t = \gamma_b \hat{\pi}_{t-1} + \gamma_f \mathrm{E}_t \hat{\pi}_{t+1} + \tilde{\lambda}_1 \hat{S}_t^N + \tilde{\lambda}_1 \left(1+\psi_R\right)[\hat{R}_t^{*D} + \left(\hat{e}_{t+1} - \hat{e}_t\right)] + \varepsilon_t , \tag{7.1}$$

where the cost channel now turns sensitive not only to financial frictions, but also to foreign shocks that stem from on one hand $\hat{R}_t^{*D}$ and on the other hand $\hat{e}_{t+1} - \hat{e}_t$. Since the open economy parameter $\tilde{\lambda}_1 \left(1+\psi_R\right)$ actually represents the net effect of $\hat{R}_t^{*D}$ and $\hat{e}_{t+1} - \hat{e}_t$ on inflation through the cost channel, we also estimate the following equation to isolate the direct impact of changes in the foreign interest rate $\hat{R}_t^{*D}$ from the indirect impact of exchange rate dynamics on inflation through the cost channel:

$$\hat{\pi}_t = \gamma_b \hat{\pi}_{t-1} + \gamma_f \mathrm{E}_t \hat{\pi}_{t+1} + \tilde{\lambda}_1 \hat{S}_t^N + \tilde{\lambda}_2 \left(1+\psi_R\right) \hat{R}_t^{*D} + \tilde{\lambda}_3 \left(1+\psi_R\right)\left(\hat{e}_{t+1} - \hat{e}_t\right) + \varepsilon_t , \tag{7.2}$$

3.2 Data Description

Our empirical investigation adopts data from Taiwan as a representative emerging small open economy whose activity is affected by the US, the benchmark foreign country. As most of the emerging markets today, Taiwan still keeps a bank-based financial system despite rapid growth in local financial markets essentially biased to the stock market at the expense of the debt market since the 1990s. The majority of firms, mainly small and medium sized, hinge exclusively on bank lending for both short-term and long-term financing. For instance, the annual statistics released by Taiwan's central bank indicate that bank lending expressed in stock terms constantly represents two-fifth of total debt for firms whereas commercial papers account for only 5% over the period between 1982 and 2005. This makes Taiwan an interesting example for empirical analysis of the cost channel with financial frictions among major emerging economies.

The sample period ranges between 1982:Q1 and 2005:Q4. Data are collected from Taiwan's central bank, Directorate-General of Budget, Accounting, and Statistics (DGBAS), Council of Labor Affairs (CLA), the AREMOS databanks by the Taiwan Economic Data Center, and FRED databanks by the St. Louis Fed. Table 1 summarizes our dataset. Monthly series are averaged to quarterly data, which yields 96 observations in our sample. The Census-X12 method is also applied to adjust obvious seasonality in certain series as explained in the note of Table 1.

3.3 Estimation Results

The GMM is adopted to estimate (6.1)-(7.2) with a set of instrument variables and orthogonality conditions. The student-*t* and *J* tests are then conducted respectively to investigate significance of each estimated parameter and effectiveness of orthogonality conditions. Major results are reported in Table 2. The *J* test does not reject the null hypothesis embodied in our over-identifying restrictions, supporting the effectiveness of the set of instrument variables as listed in the note of Table 2.

In (6.1), our modified interest-rate-augmented New Keynesian Phillips curve for a closed economy without financial frictions, all determinants for contemporaneous inflation except backward-looking inflation expectations show a significantly coefficient.

Insignificance of backward-looking inflation expectations is not necessarily inconsistent with findings in both Galí et al. (2001) and Chowdhury et al. (2006), though. The positive impact of both forward-looking inflation expectations and marginal cost of labor on inflation is in line with both theory and previous empirical works, while the significantly negative sign for $\hat{R}_t^L$ not only supports presence of the cost channel but substantiates the proof in Ravenna and Walsh (2006) as mentioned in Section 3.1.

Results in (6.2) are analogous to those in Ravenna and Walsh (2006). The two parameters estimated correspond to β and κ in their study. It is worth noting that Ravenna and Walsh (2006) do not explicitly estimate the cost channel parameter $\tilde{\lambda}_2$ that appears in (6.1). However, their analysis does validate presence of the cost channel and finds the implied κ both significantly positive as $\tilde{\lambda}$ estimated in (6.2). This seems to suggest that the net marginal cost on inflation, caused by both the firm's unit labor cost and the cost channel, remains positive.

(6.3) adopts the quintessence of Chowdhury et al. (2006) with incorporation of financial frictions in the cost channel. It is interesting to find that the cost channel effect now dominates the standard markup pricing effect on inflation, which turns insignificant compared to (6.1). Moreover, the sign of the cost channel parameter reverses, implying that financial frictions may play an important role in the price puzzle associated with the cost channel, i.e. monetary contraction may lead to a further rise in inflation. Since $\tilde{\lambda}_1$ is itself insignificant, our result implies a larger level of ψ_R vis-à-vis that estimated by Chowdhury et al. (2006) for G7 countries and substantiates the effectiveness of monetary policy in emerging economies with high financial frictions.

Investigation moves then into (7.1), the modified interest-rate-augmented New Keynesian Phillips curve for an open economy subject to both financial frictions and foreign shocks. Compared to (6.3), foreign factors seem to mitigate the impact of the cost channel (0.022) on inflation, which partially explains why the coefficient for $\hat{S}_t^N$ is again significantly positive as in (6.1). The smaller magnitude of the cost channel also reflects a reduced multiplier effect on output in a small open economy such as Taiwan.

Equation (7.2) decomposes the cost channel effect on inflation into the direct impact of the foreign interest rate and the indirect impact of exchange rate dynamics. The former seems more significantly positive while the latter shows a negative sign. It may reflect that Taiwan's cost channel is highly dependent on America's monetary policy but the exchange rate pass-through is sluggish under both imperfect capital mobility and frictions inherent in Taiwan's financial market. For example, depreciation in the local currency may actually dampen inflation because of the adverse short-term J-curve effect.

4. OPTIMAL MONETARY POLICY

This section discusses policy implications of the cost channel for the central bank. In particular, we intend to examine whether Ravenna and Walsh's (2006) conclusion that there exists, even under optimal monetary policy, a tradeoff between output gap stabilization and inflation stabilization in the face of shocks, is also valid for a small open economy that exhibits financial frictions by theory and calibration.

4.1 Policy Tradeoff

By Erceg et al. (2000), Woodford (2003), and Ravenna and Walsh (2006), optimal policy consists of minimizing a welfare loss function $L_t = \hat{\pi}_t^2 + \lambda\left(\hat{Y}_t - \hat{Y}_t^e\right)^2$ derived from the second-order approximation of the household's utility function. In addition to inflation, it contains the gap between steady-state deviation in actual output $\hat{Y}_t$ and steady-state deviation in efficient output $\hat{Y}_t^e$ expressed in (A1.7). Following Ravenna and Walsh (2006) who assume absence of inefficiency resulting from markups and tax distortions to place focus on stabilization policy, welfare loss relevant to the output gap is gauged by the "welfare" output gap $\hat{Y}_t - \hat{Y}_t^e$ rather than the "flexible-price" output gap $\hat{Y}_t - \hat{Y}_t^f$, where $\hat{Y}_t^f$, expressed in (A1.4), stands for steady-state deviation in flexible-price output. Thus, λ in the loss function measures, for the central bank, the relative importance for welfare output gap stabilization against inflation stabilization. Combining $\hat{Y}_t^e$ and $\hat{Y}_t^f$ yields:

$$\hat{Y}_t - \hat{Y}_t^e = x_t - \left(\frac{1}{\sigma+\eta}\right)\left[\left(\frac{\gamma_{1t}}{\gamma_{1t}+\gamma_{2t}}\right)\hat{\gamma}_{1t} + \left(\frac{\gamma_{2t}}{\gamma_{1t}+\gamma_{2t}}\right)\hat{\gamma}_{2t} + \hat{R}_t^f\right], \quad (8)$$

where x_t denotes the flexible-price output gap $\hat{Y}_t - \hat{Y}_t^f$. (8) differs from Ravenna and Walsh (2006) mainly in inclusion of $\hat{\gamma}_{2t}$ introduced in Section 2.5. Given its linkage with (3), $\hat{\gamma}_{2t}$ represents shocks concerned with both small openness and financial frictions.

From (8), it is perceived that the welfare output gap is composed of two parts. The first is the standard New Keynesian flexible-price output gap x_t whereas the second is related to three factors that affect welfare loss through the cost channel. They are fiscal shocks $\hat{\gamma}_{1t}$, financial shocks $\hat{\gamma}_{2t}$ (both defined in Section 2.5), and $\hat{R}_t^f$, steady-state deviation in the flexible-price nominal interest rate. In the absence of the cost channel, the welfare output gap depends only on x_t, which, in turn, relates to inflation by the standard New Keynesian inflation adjustment equation. The implication is therefore that an optimizing monetary policy intended to stabilize $\hat{Y}_t - \hat{Y}_t^e$ could be designed by stabilization of x_t which simultaneously stabilizes inflation. In other words, the central bank in search of policy optimality is not confronted with a tradeoff between output gap stabilization and inflation stabilization. As the cost channel is taken into account, the implication changes drastically. A standard policy that targets stabilization of x_t may not be optimal because any shock that leads to changes in $\hat{\gamma}_{1t}$, $\hat{\gamma}_{2t}$, or $\hat{R}_t^f$ will make the welfare output gap fluctuate.

Alternatively, a policy that permits x_t and hence inflation to fluctuate may be regarded as optimal because fluctuations in x_t serve to cushion the cost-channel effect of stochastic shocks, such as $\hat{\gamma}_{1t}$, $\hat{\gamma}_{2t}$, or $\hat{R}_t^f$, on the welfare output gap. Since inflation is not stabilized, the tradeoff inherent in the central bank's optimal policy as proposed by Ravenna and Walsh (2006) applies to a small open economy characterized with financial frictions, too.

Discussion then turns to the special case where the flexible-price equilibrium nominal interest rate is time-invariant, i.e. $\hat{R}_t^f = 0$. This may, as indicated by Ravenna and Walsh (2006), correspond to an interest rate peg, which is more likely to capture a small open economy than a closed economy. By (A3.6), optimal discretionary policy under the cost channel for period t is as:

$$\hat{\pi}_t = -\left[\frac{\lambda}{\tilde{\lambda}\left(-\sigma\psi_R + \eta\right)}\right]\left\{x_t - \frac{1}{\sigma+\eta}\left[\left(\frac{\gamma_{1t}}{\gamma_{1t}+\gamma_{2t}}\right)\hat{\gamma}_{1t} + \left(\frac{\gamma_{2t}}{\gamma_{1t}+\gamma_{2t}}\right)\hat{\gamma}_{2t}\right]\right\}, \quad (9)$$

by which the cost channel makes stabilization of $\hat{\pi}_t$ via stabilization of x_t much less a desirable policy in terms of welfare, for two reasons.

The first reason concerns the parameter for x_t. When the cost channel exists, this parameter has an absolute value equal to $\lambda/\left(\tilde{\lambda}\left(-\sigma\psi_R + \eta\right)\right)$. When the cost channel is absent, the value becomes then, by (A3.5), $\lambda/\left(\tilde{\lambda}\left(\sigma + \eta\right)\right)$. The former exceeds the latter, suggesting that any attempt to adjust x_t for price stability will actually aggravate the situation under the cost channel. The key lies in the cost-channel factor ψ_R, a function of R_t^D, Φ, and k by (7). From (3), R_t^D is subject to the foreign deposit rate and exchange rate. Similar to discussion in Section 3.1, $\hat{\pi}_t$ is hinged on ψ_R via three "sub-channels": frictions in the financial market (Φ and k), the small-country effect reflected in sensitivity to the foreign deposit rate, and economic openness that underlies dynamics of the exchange rate. Complexity inherent in these additional sub-channels makes $\hat{\pi}_t$ more volatile to adjustment in x_t. The second reason involves the whole term after x_t. Again, it is improbable that any disinflation policy via correction in x_t coincidently counteracts the exogenous effect of stochastic fiscal ($\hat{\gamma}_{1t}$) and/or financial ($\hat{\gamma}_{2t}$) shocks on $\hat{\pi}_t$ to reach eventual price stability. It can even become a conundrum in a small open economy with financial frictions since $\hat{\gamma}_{2t}$, as analyzed in Section 2.5, results from destabilizing factors that govern both domestic and international financial markets and is therefore more complicated and unpredictable. The output-inflation tradeoff for the central bank under the cost channel, from both reasons above, seems greater than the one Ravenna and Walsh (2006) assert for a closed economy.

4.2 Calibration

To deepen our discussion on optimal monetary policy, calibration is conducted to observe how the welfare output gap $\hat{Y}_t - \hat{Y}_t^e$, flexible-price output gap x_t, steady-state deviation in the nominal lending rate $\hat{R}_t^L$, and inflation $\hat{\pi}_t$ respond to a fiscal shock $\hat{\gamma}_{1t}$ under both discretionary and commitment policy, with or without the cost channel. This is particularly interesting for commitment policy because it involves the problem of time inconsistency as explained in Appendix A.3.

Specification of the parameters required for calibration is recapitulated in Table 3. Following Ravenna and Walsh (2006), the shock $\hat{\gamma}_{1t}$ is modeled as an AR(1) process, i.e. $\hat{\gamma}_{1t} = \rho_{\gamma_1}\hat{\gamma}_{1t-1} + \sigma_{\gamma_1 t}$, with $0 < \left|\rho_{\gamma_1}\right| < 1$ and ρ_{γ_1} set to 0.9. The impulse response for each of the four variables listed above is then analyzed according to the nature of optimal monetary policy and existence of the cost channel, and graphed in Figures 1 and 2. The equilibrium from which the impulse response is simulated also follows Ravenna and Walsh (2006).

Figure 1 portrays calibration results for the case of optimal discretionary policy with a 1% positive innovation to $\hat{\gamma}_{1t}$. It should be reminded that this actually implies, as clarified in Section 2.5, a positive shock to consumption but a negative shock to government spending for a given level of output. Figure 1 shows that the effect of this shock on the welfare output gap is relatively amplified vis-à-vis its effect on other variables over the initial phase as the cost channel is present. A positive rise in $\hat{\gamma}_{1t}$ by 1%, for instance, lowers $\hat{Y}_t - \hat{Y}_t^e$ by 0.55% (0.31%) in the first quarter when the cost channel is present (absent). In contrast, x_t, $\hat{R}_t^L$, and $\hat{\pi}_t$ firstly increase respectively, with the cost channel, by 0.17%, 0.06%, and 0.52% only but 0.40%, 0.09%, and 0.59% without the cost channel. Dynamics for all variables with or without the cost channel exhibit gradual convergence towards their steady-state level. Interestingly, there appears over-adjustment in $\hat{R}_t^L$ and $\hat{\pi}_t$ without the cost channel in the later phase. Finally, the flexible-price output gap x_t with the cost channel reaches its maximum in the third quarter and then declines in parallel with x_t without the cost channel.

Our results are analogous to Ravenna and Walsh (2006) in one aspect. The sign of the response for all variables is consistent with theirs. Nonetheless, in their calibration specified for a closed economy without financial frictions, the cost channel does not matter with respect to the response of both types of the output gap. Our calibration reveals that the cost channel does result in a diverged pattern for both gaps in earlier periods, with narrower x_t but wider $\hat{Y}_t - \hat{Y}_t^e$. In parallel with the theoretic view by (8), Figure 1 indicates that the adverse effect on cost-channel $\hat{Y}_t - \hat{Y}_t^e$ is actually intensified because the rise in $\hat{\gamma}_{1t}$, whose magnitude $\gamma_{1t}/(\gamma_{1t} + \gamma_{2t})$ is enlarged under financial frictions, dominates the increase in x_t. Likewise, our cost-channel inflation proves slightly lower than its counterpart at the beginning, which opposes Ravenna and Walsh (2006). The answer may be found in (A2.4). Cost-channel inflation is at first "under-shooting" because of an initially smaller rise in both x_t and $\hat{R}_t^L$. The increase in $\hat{R}_t^L$ is essentially driven by upward inflation expectations as discretionary policy cannot target future inflation in the face of $\hat{\gamma}_{1t}$. In our modeling, $\hat{R}_t^L$ is further subject to factors associated with financial frictions and small openness, which altogether dampens the effect on x_t and hence $\hat{\pi}_t$ under the cost channel, and, in turn, $\hat{R}_t^L$ due to lower inflation expectations. The promptly narrowed response of cost-channel $\hat{R}_t^L$ then leads to rapid adjustment in cost-channel x_t towards its steady-state level. In contrast, relatively asynchronous movements in x_t, $\hat{\pi}_t$, and $\hat{R}_t^L$ without the cost channel generate over-adjustment in both $\hat{\pi}_t$ and $\hat{R}_t^L$ in the later stage.

The case of optimal commitment policy is analyzed by Figure 2. With the same rise in $\hat{\gamma}_{1t}$, $\hat{Y}_t - \hat{Y}_t^e$ and x_t are boosted by 1.94% (1.58%) and 2.66% (2.30%) in the first quarter as the cost channel is present (absent) but are stabilized sooner than the case of discretionary policy. Dynamics for $\hat{R}_t^L$ are the mirror image to both output gaps, with a decline by 0.38% (0.58%) with (without) the cost channel at the beginning. First-quarter inflation reaches 0.88% (0.65%) with (without) the cost channel and then gradually falls to the steady-state level. Our results share with Ravenna and Walsh (2006) in that the cost channel does not matter much for all variables except in earlier periods. During the first two quarters, $\hat{Y}_t - \hat{Y}_t^e$ and x_t are much higher with the cost channel than without the cost channel. This implies that the rise in $\hat{\gamma}_{1t}$, now also sensitive to factors linked with financial frictions and small openness, dominates the increase in x_t to a larger extent under commitment policy than discretionary policy. The former policy actually requires an initial fall in $\hat{R}_t^L$ to restore excessive x_t and hence $\hat{\pi}_t$ to their steady-state equilibrium. Our calibration suggests that presence of the cost channel in a small open economy vis-à-vis absence of the cost channel or the cost channel in a closed economy as Ravenna and Walsh (2006) calls for smaller adjustment in $\hat{R}_t^L$ and the new steady state may be reached faster.

5. CONCLUSION

This paper attempts to deepen both theoretically and empirically the cost channel of monetary policy, whose interest rate effect on inflation is transmitted through the marginal cost inherent to the working capital of firms rather than standard demand-side mechanisms. Our modeling is extended to the case of a small open economy characterized with financial frictions. With Taiwan's dataset between 1982:Q1 and 2005:Q4, our estimation results by the GMM are essentially consistent with Chowdhury et al. (2006), who demonstrate from G7 data a stronger pass-through of the cost channel on inflation than that of conventional demand channels. Our findings further suggest that the magnitude of the cost-channel effect can be amplified in a small open economy because of the combined impact from both financial frictions and small openness on financing behavior of firms.

The issue on optimal monetary policy is also discussed. The tradeoff between output gap stabilization and inflation stabilization under the cost channel as proposed by Ravenna and Walsh (2006) proves to apply to the small open economy with financial frictions too. But the tradeoff appears greater since the central banker aiming to optimize welfare is now confronted with more destabilizing factors that complicatedly govern both domestic and international financial markets. Contrary to Ravenna and Walsh (2006), our calibration for both optimal discretionary and commitment policies indicates that the cost channel matters in dynamics of the output gap and inflation created from a positive fiscal shock. The nominal bank lending rate tends to respond less to the shock, which hence restores faster the steady-state equilibrium.

The evidence in favor of presence of the cost channel for a small open economy such as Taiwan and relevant specifics for policy implications undoubtedly shed new light on the conduct of contemporary monetary policy. In particular, the 2008-2009 global financial crisis reminds the role of financial frictions in policies that aim at macroeconomic stability. This paper shows that financial frictions and openness both should never be neglected in design of a sustainable macroeconomic policy.

APPENDIX

A.1 Flexible-price vs. Efficient Output

Given the representative household's expected present value of lifetime utility $\mathrm{E}_t \sum_{t=0}^{\infty} \beta^t \left[C_t^{1-\sigma} / (1-\sigma) - \rho N_t^{1+\eta} / (1+\eta) \right]$, optimization implies:

$$\frac{\rho N_t^{\eta}}{C_t^{-\sigma}} = w_t \Rightarrow N_t = \left(\frac{C_t^{-\sigma} w_t}{\rho} \right)^{\frac{1}{\eta}}. \tag{A1.1}$$

The representative firm's real marginal labor cost in (4) can be rewritten as:

$$\varphi_t^N = \frac{R_t^L w_t}{A_t} = \frac{1}{\Omega} \Rightarrow w_t = \frac{A_t}{\Omega R_t^L}, \tag{A1.2}$$

where Ω represents the firm's markup. With simplified production function $Y_t = A_t N_t$ and $C_t = \gamma_{1t} Y_t$ as specified in Section 2.5, flexible-price output can be solved as:

$$Y_t = A_t \left[\frac{C_t^{-\sigma} \; A_t / \Omega R_t^L}{\rho} \right]^{\frac{1}{\eta}} = \left[\frac{A_t^{1+\eta} (\gamma_{1t} Y_t)^{-\sigma}}{\Omega R_t^L \rho} \right]^{\frac{1}{\eta}} \Rightarrow Y_t^f \equiv Y_t = \left[\frac{A_t^{1+\eta} \gamma_{1t}^{\;-\sigma}}{\Omega R_t^f \rho} \right]^{\frac{1}{\sigma+\eta}}, \tag{A1.3}$$

where R_t^f denotes the flexible-price nominal interest rate. Log-linearization of (A1.3) then derives deviation of flexible-price output from its steady-state level:

$$\hat{Y}_t^f = \left(\frac{1}{\sigma+\eta} \right) \left[(1+\eta) \hat{A}_t - \sigma \hat{\gamma}_{1t} - \hat{R}_t^f \right]. \tag{A1.4}$$

In contrast, the efficient output level is based on the social planner's problem that is to maximize the household's expected lifetime utility subject to the aggregate resource constraint as specified in Section 2.5, i.e. $Y_t = \gamma_{1t} Y_t + \gamma_{2t} Y_t + (1 - \gamma_{1t} - \gamma_{2t}) Y_t$ with $Y_t = A_t N_t$. First-order conditions for C_t, N_t, and G_t are respectively $U_c - \lambda = 0$, $U_N + \lambda A_t + \mu(1-\gamma_{1t}-\gamma_{2t}) A_t = 0$, and $-\lambda - \mu = 0$, which yields $U_N / U_C = (\gamma_{1t} + \gamma_{2t}) A_t$. Combining this last equation with $U_N / U_C = \rho N_t^{\eta} / C_t^{-\sigma} = \rho (Y_t / A_t)^{\eta} / (\gamma_{1t} Y_t)^{-\sigma}$, we obtain:

$$\frac{\rho\gamma_{1t}^{\sigma}Y_t^{\sigma+\eta}}{A_t^{\eta}}=(\gamma_{1t}+\gamma_{2t})A_t \Rightarrow Y_t^{\sigma+\eta}=\left[\frac{A_t^{1+\eta}\gamma_{1t}^{-\sigma}(\gamma_{1t}+\gamma_{2t})}{\rho}\right], \qquad \text{(A1.5)}$$

which yields the expression of efficient output Y_t^e as:

$$Y_t^e \equiv Y_t=\left[\frac{A_t^{1+\eta}\gamma_{1t}^{-\sigma}(\gamma_{1t}+\gamma_{2t})}{\rho}\right]^{\frac{1}{\sigma+\eta}}. \qquad \text{(A1.6)}$$

Log-linearization of (A1.6) then derives deviation of Y_t^e from its steady-state level:

$$\hat{Y}_t^e=\left(\frac{1}{\sigma+\eta}\right)\left[(1+\eta)\hat{A}_t+\left(\frac{\gamma_{1t}}{\gamma_{1t}+\gamma_{2t}}-\sigma\right)\hat{\gamma}_{1t}+\left(\frac{\gamma_{2t}}{\gamma_{1t}+\gamma_{2t}}\right)\hat{\gamma}_{2t}\right]. \qquad \text{(A1.7)}$$

A.2 Flexible-price Output Gap

Log-linearization of (5), $C_t = \gamma_{1t}Y_t$, and $\beta^t \mathrm{E}_t\left[\left(\frac{P_t}{P_{t+1}}\right)\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\right]=\frac{1}{R_t^D}$ as one condition for the household's intertemporal optimization yield:

$$-\sigma\hat{C}_t=\mathrm{E}_t\left(-\sigma\hat{C}_{t+1}\right)+\hat{r}_t^D \Rightarrow -\sigma\left(\hat{\gamma}_{1t}+\hat{Y}_t\right)=\mathrm{E}_t\left[-\sigma\left(\hat{\gamma}_{1t+1}+\hat{Y}_{t+1}\right)\right]+\hat{r}_t^D$$

$$\Rightarrow \hat{Y}_t=\mathrm{E}_t\left(\hat{\gamma}_{1t+1}-\hat{\gamma}_{1t}\right)+\mathrm{E}_t\hat{Y}_{t+1}-\frac{1}{\sigma}\hat{r}_t^D$$

$$\Rightarrow \hat{Y}_t-\hat{Y}_t^f=\mathrm{E}_t\left(\hat{\gamma}_{1t+1}-\hat{\gamma}_{1t}\right)+\mathrm{E}_t\left(\hat{Y}_{1t+1}-\hat{\gamma}_{1t}\right)+\mathrm{E}_t\left(\hat{Y}_{t+1}^f-\hat{Y}_t^f\right)-\frac{1}{\sigma}\hat{r}_t^D, \qquad \text{(A2.1)}$$

where $\hat{r}_t^D=\hat{R}_t^D-\mathrm{E}_t\hat{\pi}_{t+1}$. Define $\hat{r}_t^f=\sigma\mathrm{E}_t\left(\hat{Y}_{t+1}^f-\hat{Y}_t^f\right)+\sigma\mathrm{E}_t\left(\hat{\gamma}_{1t+1}-\hat{\gamma}_{1t}\right)$, the flexible-price output gap can be expressed as:

$$\hat{Y}_t-\hat{Y}_t^f=\mathrm{E}_t\left(\hat{Y}_{t+!}-\hat{Y}_{t+1}^f\right)-\frac{1}{\sigma}\left(\hat{r}_t^D-\hat{r}_t^f\right)=\mathrm{E}_t\left(\hat{Y}_{t+1}-\hat{Y}_{t+1}^f\right)-\frac{1}{\sigma}\left[\left(\frac{1}{1+\psi_R}\right)\hat{r}_t^L-\hat{r}_t^f\right]$$

$$= \mathrm{E}_t\left(\hat{Y}_{t+1} - \hat{Y}_{t+1}^f\right) - \frac{1}{\sigma}\left[\left(\frac{1}{1+\psi_R}\right)\left(\hat{R}_t^L - \mathrm{E}_t\hat{\pi}_{t+1}\right) - \hat{r}_t^f\right], \tag{A2.2}$$

where $\hat{r}_t^L = \hat{R}_t^L - \mathrm{E}_t\hat{\pi}_{t+1}$ and ψ_R that connects lending and deposit rates is specified in (7). Let $\hat{Y}_t - \hat{Y}_t^f = x_t$, (A2.2) can be rewritten as:

$$x_t = \mathrm{E}_t x_{t+1} - \frac{1}{\sigma}\left(\frac{1}{1+\psi_R}\right)\left(\hat{R}_t^L - \mathrm{E}_t\hat{\pi}_{t+1}\right) + u_t, \text{ where } u_t = \frac{1}{\sigma}\hat{r}_t^f. \tag{A2.3}$$

Finally, given $C_t = \gamma_{1t}Y_t$, log-linearization of both $S_t^N = (w_tN_t)/Y_t$ and (A1.1) links the flexible-price output gap x_t with our modified interest-rate-augmented New Keynesian Phillips curve for a closed economy presented in Section 3.1:

$$\begin{aligned}
\hat{\pi}_t &= \gamma_b\hat{\pi}_{t-1} + \gamma_f\mathrm{E}_t\hat{\pi}_{t+1} + \tilde{\lambda}\left(\hat{S}_t^N + \hat{R}_t^L\right) \\
&= \gamma_b\hat{\pi}_{t-1} + \gamma_f\mathrm{E}_t\hat{\pi}_{t+1} + \tilde{\lambda}\left[\left(\hat{w}_t + \hat{N}_t - \hat{Y}_t\right) + \hat{R}_t^L\right] \\
&= \gamma_b\hat{\pi}_{t-1} + \gamma_f\mathrm{E}_t\hat{\pi}_{t+1} + \tilde{\lambda}\left[\eta\left(\hat{Y}_t - \hat{A}_t\right) + \sigma\left(\hat{\gamma}_{1t} + \hat{Y}_t\right) + \left(\hat{Y}_t - \hat{A}_t\right) - \hat{Y}_t + \hat{R}_t^L\right] \\
&= \gamma_b\hat{\pi}_{t-1} + \gamma_f\mathrm{E}_t\hat{\pi}_{t+1} + \tilde{\lambda}\left[-(1+\eta)\hat{A}_t + \sigma\hat{\gamma}_{1t} + (\sigma+\eta)\hat{Y}_t + \hat{R}_t^f - \hat{R}_t^f + \hat{R}_t^L\right] \\
&= \gamma_b\hat{\pi}_{t-1} + \gamma_f\mathrm{E}_t\hat{\pi}_{t+1} + \tilde{\lambda}(\sigma+\eta)\left(\hat{Y}_t - \hat{Y}_t^f\right) + \tilde{\lambda}\left(\hat{R}_t^L - \hat{R}_t^f\right).
\end{aligned} \tag{A2.4}$$

A.3 Optimal Monetary Policy

Following Ravenna and Walsh (2006), the special case of $\hat{R}_t^f = 0$ is examined. We begin with optimal discretionary policy where optimization for the central banker consists of choosing, under the cost channel, an optimal path for $\hat{R}_t^L$ that minimizes

$L_t = \hat{\pi}_t^2 + \lambda\left(\hat{Y}_t - \hat{Y}_t^e\right)^2$, the welfare loss, subject to x_t in (A2.3) and $\hat{\pi}_t$ in (A2.4) but modified with $\hat{R}_t^f$ set to zero. The welfare output gap defined as $\hat{Y}_t - \hat{Y}_t^e$ and expressed in (8) is also modified with $\hat{R}_t^f$ set to zero. In order to contrast policy implications between absence and presence of the cost channel, we insert a dummy variable δ as the coefficient for $\hat{R}_t^L$ into (A2.4). The value of δ equals one (zero) when the cost channel is present (absent). Let X_t and ϕ_t be the respective Lagrangian multipliers for (A2.3) and now modified (A2.4), first-order conditions for x_t, $\hat{\pi}_t$, and $\hat{R}_t^L$ when $\delta = 1$ are:

$$-\lambda\left\{x_t - \frac{1}{\sigma+\eta}\left[\left(\frac{\gamma_{1t}}{\gamma_{1t}+\gamma_{2t}}\right)\hat{\gamma}_{1t} + \left(\frac{\gamma_{2t}}{\gamma_{1t}+\gamma_{2t}}\right)\hat{\gamma}_{2t}\right]\right\} + X_t - \phi_t \tilde{\lambda}(\sigma+\eta) = 0, \qquad \text{(A3.1)}$$

$$\hat{\pi}_t = \phi_t, \qquad \text{(A3.2)}$$

$$X_t = \sigma\delta\tilde{\lambda}\phi_t(1+\psi_R). \qquad \text{(A3.3)}$$

(A3.2) and (A3.3) are then inserted into (A3.1) to derive $\hat{\pi}_t$ for optimal discretionary monetary policy:

$$-\lambda\left\{x_t - \frac{1}{\sigma+\eta}\left[\left(\frac{\gamma_{1t}}{\gamma_{1t}+\gamma_{2t}}\right)\hat{\gamma}_{1t} + \left(\frac{\gamma_{2t}}{\gamma_{1t}+\gamma_{2t}}\right)\hat{\gamma}_{2t}\right]\right\} + \sigma\delta\tilde{\lambda}\hat{\pi}_t(1+\psi_R) - \pi_t\tilde{\lambda}(\sigma+\eta) = 0$$

$$\Rightarrow\left[\tilde{\lambda}\sigma + \tilde{\lambda}\eta - \sigma\delta\tilde{\lambda}(1+\psi_R)\right]\hat{\pi}_t = -\lambda\left\{x_t - \frac{1}{\sigma+\eta}\left[\left(\frac{\gamma_{1t}}{\gamma_{1t}+\gamma_{2t}}\right)\hat{\gamma}_{1t} + \left(\frac{\gamma_{2t}}{\gamma_{1t}+\gamma_{2t}}\right)\hat{\gamma}_{2t}\right]\right\}$$

$$\hat{\pi}_t = -\left(\frac{\lambda}{\tilde{\lambda}\left\{\sigma\left[1-\delta\left(1+\psi_R\right)\right]+\eta\right\}}\right)\left\{x_t - \frac{1}{\sigma+\eta}\left[\left(\frac{\gamma_{1t}}{\gamma_{1t}+\gamma_{2t}}\right)\hat{\gamma}_{1t} + \left(\frac{\gamma_{2t}}{\gamma_{1t}+\gamma_{2t}}\right)\hat{\gamma}_{2t}\right]\right\}. \qquad \text{(A3.4)}$$

(A3.5) and (A3.6) below correspond to this policy when δ = 0 and δ = 1 respectively:

$$\hat{\pi}_t = -\left[\frac{\lambda}{\tilde{\lambda}(\sigma+\eta)}\right]\left\{x_t - \frac{1}{\sigma+\eta}\left[\left(\frac{\gamma_{1t}}{\gamma_{1t}+\gamma_{2t}}\right)\hat{\gamma}_{1t} + \left(\frac{\gamma_{2t}}{\gamma_{1t}+\gamma_{2t}}\right)\hat{\gamma}_{2t}\right]\right\}. \tag{A3.5}$$

$$\hat{\pi}_t = -\left[\frac{\lambda}{\tilde{\lambda}(-\sigma\psi_R+\eta)}\right]\left\{x_t - \frac{1}{\sigma+\eta}\left[\left(\frac{\gamma_{1t}}{\gamma_{1t}+\gamma_{2t}}\right)\hat{\gamma}_{1t} + \left(\frac{\gamma_{2t}}{\gamma_{1t}+\gamma_{2t}}\right)\hat{\gamma}_{2t}\right]\right\}. \tag{A3.6}$$

As to the optimal commitment policy, it becomes more complicated as there exists an inherent problem of time inconsistency between implied $\hat{\pi}_t$ and $\hat{\pi}_{t+i}$ for the central bank. Optimization consists of minimizing expected future welfare loss at period t, subject to x_{t+i} and $\hat{\pi}_{t+i}$. The resultant contemporaneous $\hat{\pi}_t$ for optimal commitment policy appears identical to (A3.4), while the timeless pre-commitment policy for all t can be referred, for instance, to Svensson and Woodford (2000).

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TABLE 1. DATA DESCRIPTION

Abbreviation	Description	Frequency	Data Source
RGDP	Real Gross Domestic Product (GDP)	Quarterly	AREMOS
GDPDEF	GDP Deflator	Quarterly	AREMOS
CPI	Consumer Price Index	Quarterly	DGBAS
RL	Base Lending Rate	Monthly	Taiwan's Central Bank
RF	US Federal Funds Rate	Quarterly	FRED
RDY	One-year Time Deposit Rate	Monthly	Taiwan's Central Bank
RS	90-day Commercial Paper Rate	Monthly	Taiwan's Central Bank
ER	Nominal Exchange Rate (USD/TWD)	Monthly	Taiwan's Central Bank
RULC	Real Unit Labor Cost Index	Quarterly	CLA
HC	Hourly Compensation Index	Quarterly	CLA

Note: The sample is over the period 1982:Q1 – 2005:Q4, amounting to 96 observations. Monthly series are averaged to quarterly data. AREMOS is made by the Taiwan Economic Data Center. DGBAS stands for Taiwan's Directorate-General of Budget, Accounting, and Statistics. FRED is run by the St. Louis Fed. CLA stands for Taiwan's Council of Labor Affairs. RULC (deflated by GDPDEF) and HC are for the manufacturing sector. The Census-X12 method is applied to adjust seasonality in the series of RGDP, GDPDEF, RULC, and HC.

TABLE 2. ESTIMATION OF THE MODIFIED INTEREST-RATE-AUGUMENTED NEW KEYNESIAN PHILLIPS CURVE

(6.1)-(6.3): $\hat{\pi}_t = \gamma_b \hat{\pi}_{t-1} + \gamma_f \mathrm{E}_t \hat{\pi}_{t+1} + \tilde{\lambda}_1 \hat{S}_t^N + \tilde{\lambda}_2 \hat{R}_t^L + \varepsilon_t$; $\hat{\pi}_t = \gamma_f \mathrm{E}_t \hat{\pi}_{t+1} + \tilde{\lambda}(\hat{S}_t^N + \hat{R}_t^L) + \varepsilon_t$; $\hat{\pi}_t = \gamma_f \mathrm{E}_t \hat{\pi}_{t+1} + \tilde{\lambda}_1 \hat{S}_t^N + \tilde{\lambda}_1 (1+\psi_R) \hat{R}_t^D + \varepsilon_t$

(7.1)-(7.2): $\hat{\pi}_t = \gamma_f \mathrm{E}_t \hat{\pi}_{t+1} + \tilde{\lambda}_1 \hat{S}_t^N + \tilde{\lambda}_1 (1+\psi_R)[\hat{R}_t^{*D} + (\hat{e}_{t+1} - \hat{e}_t)] + \varepsilon_t$; $\hat{\pi}_t = \gamma_f \mathrm{E}_t \hat{\pi}_{t+1} + \tilde{\lambda}_1 \hat{S}_t^N + \tilde{\lambda}_2 (1+\psi_R) \hat{R}_t^{*D} + \tilde{\lambda}_3 (1+\psi_R)(\hat{e}_{t+1} - \hat{e}_t) + \varepsilon_t$

	Closed Economy without/with Financial Frictions (FF)						**Open Economy with Foreign Shocks**			
	Equation (6.1): No FF Cost Channel Effect		**Equation (6.2): No FF** Net Marginal Cost Effect		**Equation (6.3): FF** Cost Channel Effect		**Equation (7-1): FF** Net Cost Channel Effect		**Equation (7-2): FF** Separate Cost Channel Effect	
γ_b	-0.063	(0.066)								
γ_f	0.478***	(0.075)	0.608***	(0.067)	0.147**	(0.059)	0.479***	(0.076)	0.261***	(0.078)
$\tilde{\lambda}_1$	0.047***	(0.004)			0.003	(0.004)	0.026***	(0.003)	0.006	(0.005)
$\tilde{\lambda}_2$	-0.047**	(0.021)								
$\tilde{\lambda}$			0.020***	(0.003)						
$\tilde{\lambda}_1(1+\psi_R)$					0.147***	(0.015)	0.022**	(0.009)		
$\tilde{\lambda}_2(1+\psi_R)$									0.053***	(0.014)
$\tilde{\lambda}_3(1+\psi_R)$									-0.043*	(0.022)

Note: GMM estimation results. Standard errors in parenthesis and ***, **, and * for the 1%, 5%, and 10% significance level. The null hypothesis of over-identifying restrictions cannot be rejected in all estimations. π_t is the inflation rate based on the seasonally adjusted GDP deflator (GDPDEF in Table 1). S_t^N is seasonally adjusted real unit labor cost (RULC in Table 1) in logarithm. R_t^L and R_t^{*D} are proxied by RL and RF in Table 1. e_t is the exchange rate (ER in Table 1) in logarithm. For a given variable x_t, $\hat{x}_t$ refers to its steady-state deviation and is calculated by $x_t - \bar{x}$ (multiplied by 100 for the cases of S_t^N and e_t). Valid instrument variables include five lags of $\hat{\pi}_t$, $\hat{S}_t^N$, $\hat{R}_t^L$, the spread between RDY and RS in Table 1, inflation rates based on CPI and HC in Table 1, and the Hodric-Prescott-filter (HPF) output gap defined as the difference between seasonally adjusted RGDP (Table 1) in logarithm and HPF potential output in logarithm, multiplied by 100. Note that equations (6.2)-(7.2) are slightly different from those presented in text because $\hat{\pi}_{t-1}$ is omitted for insignificant results. The sample covers 96 quarters over the period 1982:Q1 – 2005:Q4.

TABLE 3. Parameterization for Calibration

Parameter	Value	Description	Source
β	0.99	Household's Discount Factor	RW (2006)
σ	0.3	1/(Elasticity of Consumption Intertemporal Substitution)	Trial-and-Error
η	1	1/(Elasticity of Labor Supply Intertemporal Substitution)	RW (2006)
γ_1	0.5819	Ratio of Steady-state Consumption to Output	Historical Mean
γ_2	0.2685	Ratio of Steady-state Financial Activity to Output	Historical Mean
ψ_R	0.25	Degree of Frictions in the Financial Market	CHS (2006)
γ_b	0.3	Weight for Firm's Backward-looking Pricing	CHS (2006)
γ_f	0.6	Weight for Firm's Forward-looking Pricing	CHS (2006)
λ	0.25	Weight for Central Bank's Output Gap Stabilization	RW (2006)
$\rho_{\gamma 1}$	0.9	AR(1) Coefficient of Fiscal Shock $\hat{\gamma}_{1t}$	RW (2006)
$\sigma_{\gamma 1}$	1	Standard Error of Fiscal Shock $\hat{\gamma}_{1t}$	RW (2006)

Note: RW (2006) and CHS (2006) refer to Ravenna and Walsh (2006) and Chowdhury et al. (2006). The historical mean for γ_1 and γ_2 is calculated from our data, with γ_2 imputed from $(1 - \gamma_1 - \gamma_2)$, the ratio of steady-state government spending to output. The discount factor β is set 0.9 by Galí and Gertler (1999) and Galí et al. (2001), and 0.99 by Malik (2003a, 2003b) and Ravenna and Walsh (2006). Our calibration adopts the latter but results are found the same when β is between 0.9 and 0.99.

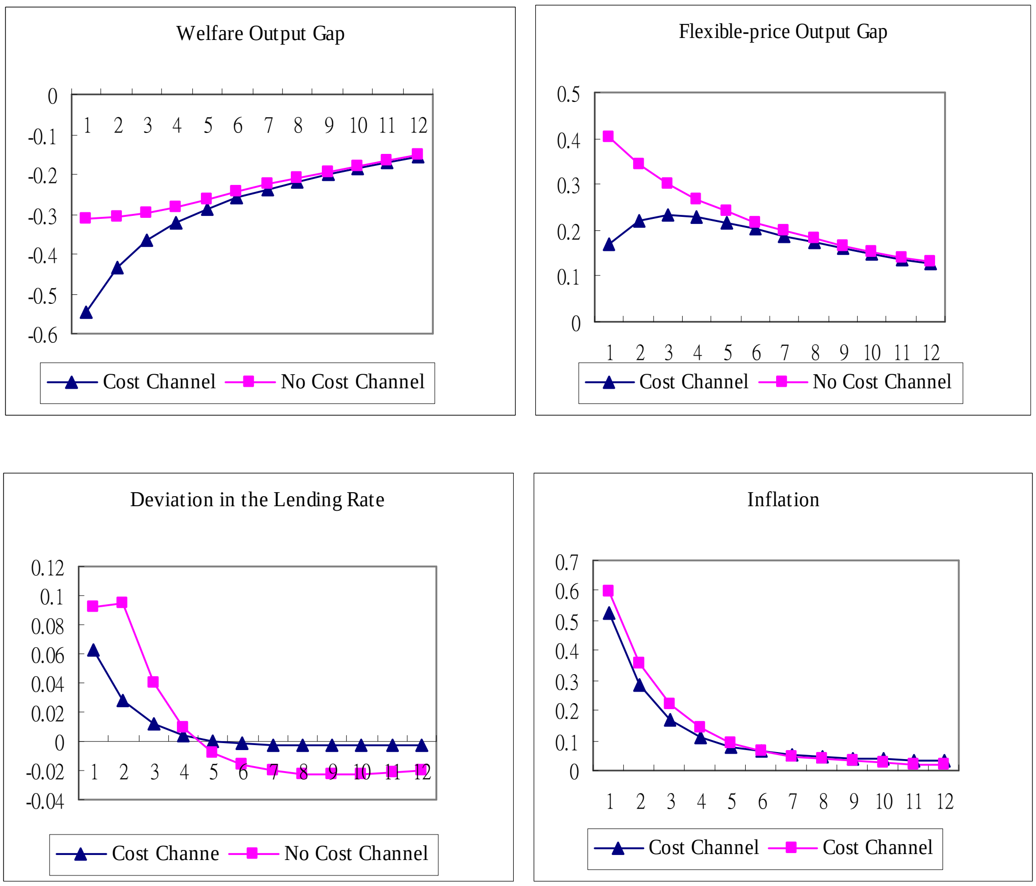

Figure 1. Response to a Fiscal Shock under Optimal Discretionary Policy

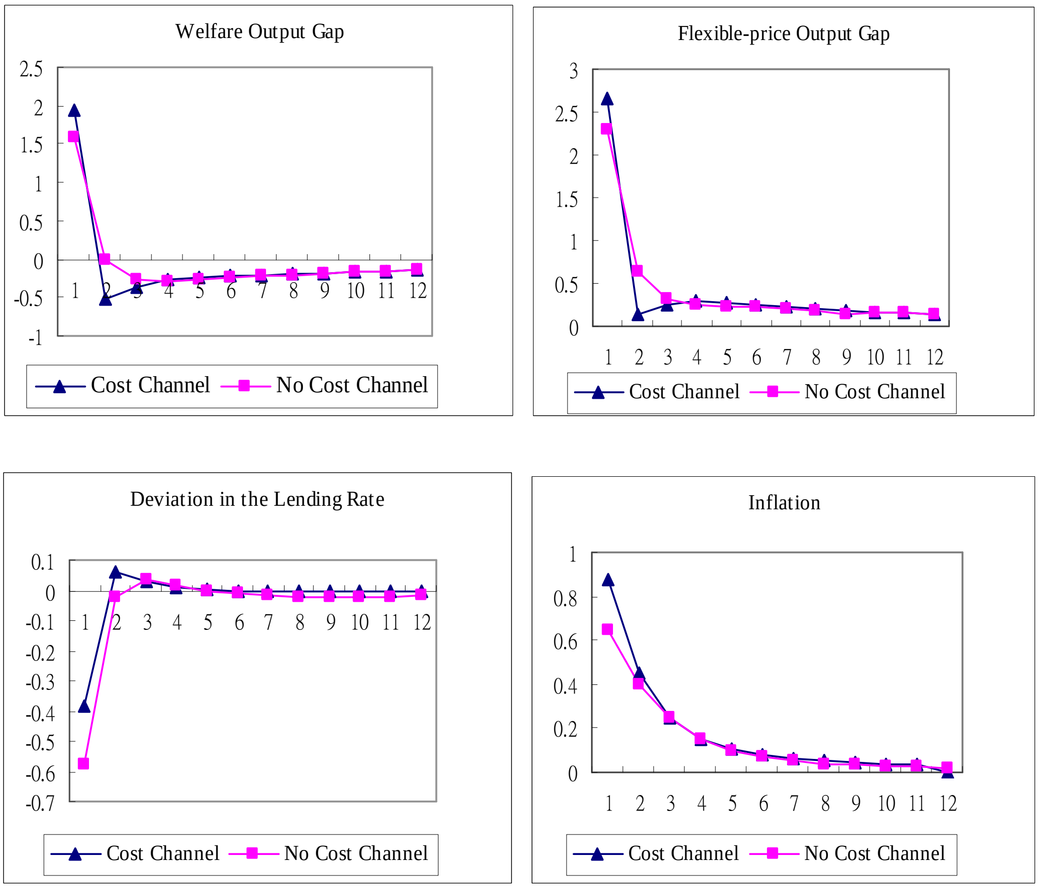

FIGURE 2. Response to a Fiscal Shock under Optimal Commitment Policy