# Optimal Monetary Policy in Response to Cost-Push Shocks: The Impact of Central Bank Communication*

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This paper argues that a central bank's optimal policy in response to a cost-push shock depends upon its disclosure regime. More precisely, a credible central bank may find it optimal to implement an accommodative monetary policy in response to a positive cost-push shock whenever the uncertainty surrounding its monetary instrument is high. Indeed, the degree of the central bank's transparency influences the effectiveness of its policy to stabilize inflation in terms of output gap. The effectiveness, in turn, determines whether it will implement an expansionary or contractionary policy in response to a positive cost-push shock.

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## 1. Introduction

How should a central bank respond to a cost-push shock? Since cost-push shocks simultaneously create both an upsurge in inflation

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and a negative output gap, the optimal central bank response is highly controversial. The very nature of a cost-push shock gives rise to a dilemma for the central bank. The bank can either ease its monetary policy to accommodate the negative output gap or tighten it to fight the upsurge in inflation. Under what conditions will a central bank decide to pursue the first strategy rather than the second? This paper aims to show that the optimal response to a cost-push shock is driven by the communication regime followed by the central bank.

During the 1970s, as the price for oil rose dramatically, many countries experienced large positive cost-push shocks. In an empirical analysis, Clarida, Galí, and Gertler (2000) show that the Federal Reserve eased its monetary policy in response to these oil shocks. Indeed, they argue (p. 168) that "it is hard to imagine . . . that the 1973 oil shock alone could have generated high inflation . . . in the absence of an accommodating monetary policy." While these authors show that monetary policy was accommodative in the pre-Volcker era and restrictive during the Volcker-Greenspan era, their paper does not provide any rationale for such a change. More generally, it remains unclear why monetary policy apparently accommodated the large positive cost-push shocks in the 1970s but not in the 1990s.

Over the last decades, there has been a switch in central banks' communication strategy: from secrecy toward greater transparency.[1] We show that such a change in transparency has strong implications for how to optimally deal with a cost-push shock: the optimal policy a central bank should adopt in response to a cost-push shock depends upon its disclosure regime. De Long (1997) largely documents the evolution in the perception of the response to be adopted in the event of a cost-push shock. He underlines central bankers' concern for the impact of a restrictive monetary policy on output and, more particularly, on unemployment. Our model shows that the trade-off between inflation and output strongly depends on the level of transparency in the economy. In the case of opacity, the trade-off does not promote inflation stabilization. Given opaque communication, the

[1] An emblematic example is the publication of the monetary instrument by the Federal Reserve from 1994 on. The increase in transparency in the conduct of monetary policy in recent years is studied by Dincer and Eichengreen (2006) and Eijffinger and Geraats (2006).

central bank can only reduce inflation at the cost of a strong decrease in output. Increasing the central bank's transparency reduces the cost of stabilizing inflation. De Long argues that the main reason for the inflation in the '70s lies in the "shadow of the Great Depression." Our model suggests that the central banks in the '70s had good reasons to fear recession (De Long 1997) or to emphasize output-gap stabilization (Orphanides 2005). The opacity characterizing policy at that time would have caused strong contractions in output.

We propose a monetary policy model under monopolistic competition with heterogeneous information on the cost-push shocks affecting the economy. We base our analysis on the literature in the vein of Adam (2007), Hellwig (2002), Morris and Shin (2002), and Woodford (2003) who—among others—recently emphasized that, in an economy characterized by strategic complementarities, heterogeneous information can lead to realistic dynamics of transmission mechanisms.[2] Our approach is unique in that we analyze the role of the central bank's communication regime for the conduct of monetary policy under the imperfect-information hypothesis. We consider a central bank that has no inflationary bias and whose preferences are perfectly known by the private sector.[3] Both the central bank and firms are uncertain about the true state of the economy and receive private signals on cost-push shocks. We assume that the communication regime of the central bank is exogenous and defined as follows. The central bank can be transparent, disclosing all the information it has about the macroeconomic conditions. Or it can be opaque, in the sense that it does not disclose any information about macroeconomic conditions. We can also distinguish any intermediate situation in which the central bank discloses information about macroeconomic conditions in a more or less ambiguous manner.[4] Firms receive a signal on the monetary instrument of the central bank according to the degree of transparency of the central bank

[2]See also Mankiw and Reis (2002).

[3]We concentrate on well-established and credible central banks, i.e., without inflationary bias. This is natural in the current context of central bank independence and historically—and durable—low levels of inflation of most OECD countries.

[4]The notion of transparency considered in this paper is therefore economic transparency according to the classification of Geraats (2002).

with respect to its policy. While the central bank's disclosure does not contain any valuable information under opacity, the monetary instrument is common knowledge among firms under transparency. Taking into account the potentially informative role of the monetary instrument[5] is in line with empirical evidence.[6] We derive the optimal monetary policy depending on the communication regime of the central bank (opacity vs. transparency cases and any intermediate situation) when imperfect information is responsible for money non-neutrality.

The model is as follows. In an economy where firms' prices are strategic complements, the effectiveness of monetary policy on the pricing rule of firms is driven by the disclosure of the central bank, since it determines the fundamental and strategic uncertainty surrounding its monetary instrument. The information disclosed by the central bank influences the reaction of the price level to monetary policy and thus influences the extent to which the central bank can deal with the trade-off generated by cost-push shocks. Under transparency, as the monetary instrument is common knowledge among firms, optimal monetary policy always contracts the nominal demand. In contrast, opacity increases fundamental and strategic uncertainty about the central bank's action, thereby reducing the effectiveness of monetary policy on the price level. Contracting the nominal demand is ineffective for reducing the price level. The central bank may find it optimal to reduce the output gap by expanding its instrument.[7] However, opacity is not a sufficient condition for the optimal monetary policy to be accommodative. The sign of the policy coefficient depends on the relationship between the degree of

[5]Here our work relates to Baeriswyl and Cornand (2006) and Walsh (2006, 2007), who consider that the monetary instrument is both an action and a vehicle for information.

[6]In an empirical analysis of U.S. data, Romer and Romer (2000) show that the observation of the monetary instrument highly influences the formation of market expectations. Moreover, Demiralp and Jordà (2002) emphasize the relevance of central bank communication to manipulate market expectations. They show, in particular, that the publication of the instrument rate targeted by the policy board of the Federal Reserve since 1994 has increased the effectiveness of monetary policy to shape market expectations (via an announcement effect).

[7]While Goodfriend and King (2005) argue that the lack of a central bank's credibility increases the cost of disinflation, our analysis emphasizes the role of a central bank's transparency as a determinant of the costs of inflation stabilization.

strategic complementarities, the preference of the central bank for output-gap stabilization, and the relative precision of firms' private information.

The remainder of this paper is structured as follows. Section 2 outlines a monopolistic-competition economy, in which firms' pricing decisions represent strategic complements. Section 3 considers a benchmark case under common information and develops intuition for our main result. Section 4 examines the case of heterogeneous information and shows that the optimal monetary policy under opacity may be to accommodate a cost-push shock. We also show that small changes in the degree of transparency or in preferences may have large effects on the optimal monetary policy. Finally, section 5 concludes.

## 2. The Economy

The model is derived from an economy with flexible prices, populated by a continuum of monopolistic competitive firms and a central bank. The economy is affected by stochastic cost-push shocks that are normally distributed:

$$u \sim N\big(0, \sigma_u^2\big).$$

Nominal aggregate demand is determined by the monetary instrument $I$ set by the central bank.

### *2.1 Firms*

The behavior of firms consists in choosing a price. Under monopolistic competition à la Dixit-Stiglitz, firms set their price as a function of their expectations of the overall price level $p$, the real output gap $y$, and the cost-push shock $u$.[8] One can show that the optimal price of firm $i$ is given by

$$p_i = \mathbb{E}_i[p + \xi y + u], \tag{1}$$

where variables are expressed as percentage deviations from the deterministic steady state. The pricing rule (1) captures the strategic complementarities in prices. Indeed, each firm $i$ sets its price

[8]For the microfounded derivation, see Adam (2007) or Woodford (2003).

according to its expectation about both fundamentals (the output gap $y$ and the cost-push shock $u$) and the average action of others, the overall price level $p$.

The parameter $\xi$ determines to what extent the optimal price responds to the output gap. As we assume below, the central bank determines the nominal aggregate demand through its monetary instrument $I$. Using the fact that the nominal aggregate demand $I$ is by definition equal to $y + p$, we rewrite the pricing rule (1) as

$$p_i = \mathbb{E}_i[(1 - \xi)p + \xi I + u]. \tag{2}$$

In the whole paper, we realistically assume that prices are strategic complements and impose $0 < \xi \leq 1$. When $\xi$ decreases, the optimal price setting responds less strongly to fundamentals ($I$ and $u$) and more strongly to the strategic term, the overall price level $p$: the degree of strategic complementarities increases.

While prices are flexible in our model, heterogeneous information among firms may account for non-neutral effects of monetary policy. Indeed, Hellwig (2002) or Woodford (2003) show that the lack of information about each other's expectations (higher-order uncertainty) yields nominal adjustment delays of prices.

### *2.2 Central Bank*

Following much of the literature, we assume that the central bank minimizes the deviation of both the output gap $y$ and the price level $p$ from their respective target owing to its monetary instrument $I$. The central bank's optimization problem corresponding to flexible inflation targeting can be described by its loss,

$$L = \min_I \mathbb{E}_{cb}[\lambda y^2 + p^2], \tag{3}$$

where $\lambda$ is the weight assigned to the output-gap variability.

Note that the central bank has no incentive to push the output above its natural level. For the sake of simplicity, as mentioned above, we assume that the central bank directly controls the nominal aggregate demand with its monetary instrument $I$.

## 3. Common Information

Standard monetary policy analysis assumes that information is common knowledge among firms. While this paper deals with monetary policy under heterogeneous information, the current section derives, as a benchmark, the optimal monetary policy under common knowledge.

When information is perfect and common to all firms, each firm sets the same price ($p_i = p$). The pricing rule (2) then simplifies to

$$p_i = p = I + \frac{1}{\xi}u.$$

The impact of cost-push shocks $u$ on the price level increases with the degree of strategic complementarities $1-\xi$. When $\xi$ is small, nominal aggregate demand is given a lower weight in the pricing rule, which increases the relative weight assigned to cost-push shocks.

The central bank chooses its instrument to minimize its loss (3) based on its signal on the cost-push shock: $u_{cb} = u + \mu$, with $\mu \sim N(0, \sigma_\mu^2)$. The monetary instrument is linear in central bank's signal $u_{cb}$: $I = \nu u_{cb}$, where $\nu$ stands for the monetary policy coefficient. When the central bank has perfect information about the shock, its monetary instrument simplifies to $I = \nu u$.

The loss under perfect information can be written as

$$L = \lambda \left(-\frac{1}{\xi}u\right)^2 + \left[\left(\frac{1}{\xi} + \nu\right)u\right]^2,$$

and minimizing it yields the following optimal monetary policy:

$$\nu = -\frac{1}{\xi}. \tag{4}$$

The corresponding unconditional expected loss is a function of the variance of cost-push shocks:

$$\mathbb{E}(L) = \frac{\lambda}{\xi^2}\sigma_u^2.$$

The optimal monetary policy coefficient $\nu$ states that the central bank contracts nominal aggregate demand by $-\frac{1}{\xi}$ when the cost-push shock increases by one unit. Contracting aggregate demand whenever cost-push shocks are positive is known as *leaning against the wind*.[9] As the price level increases in the case of a positive cost-push shock, the central bank contracts the nominal aggregate demand to stabilize it. The strength of the central bank's response increases with the degree of strategic complementarities.

The optimal monetary policy derived in this section illustrates that under common information, the central bank finds it optimal to stabilize the price level. By contrast, as we shall see in the next section, when the monetary instrument is not common knowledge among firms, optimal monetary policy may call for output-gap stabilization.

## 4. Heterogeneous Information

We now turn to the more realistic case where firms have heterogeneous information about the state of the economy. We apply the methodology of Morris and Shin (2002) to our optimal monetary policy framework. These authors emphasize the relevance of public information in an economy characterized by strategic complementarities and heterogeneous information.

### *4.1 Information Structure*

The information structure in the economy is as follows. Let's recall that the central bank receives a private signal on the cost-push shock that deviates from the true fundamental value by an error term that is normally distributed:

$$u_{cb} = u + \mu, \text{ with } \mu \sim N\big(0, \sigma_\mu^2\big).$$

[9]There is wide agreement among economists that a good monetary policy typically calls for leaning against the wind. The general idea is to keep inflation under control by contracting the economy or equivalently taking a restrictive action whenever inflation is above target. Note that some authors adopt other definitions for this expression. For instance, Schwartz (2003, p. 1025) argues that "the Fed should 'lean against the wind,' by taking restrictive action during periods of economic expansion and expansionary action during periods of economic contraction." By contrast, Clarida, Galí, and Gertler (1999, p. 1672) say that "the central bank pursues a 'lean against the wind' policy: Whenever inflation is above target, contract demand below capacity (by raising the interest rate)."

The central bank chooses its instrument to minimize (3). The optimal instrument rule of the central bank is a linear function of its signal and can be written as

$$I = \nu(u + \mu). \tag{5}$$

Each firm $i$ receives a private signal on the cost-push shock $u_i$. The private signal of each firm deviates from the true cost-push shock by an error term that is normally distributed:

$$u_i = u + \rho_i, \text{ with } \rho_i \sim N\big(0, \sigma_\rho^2\big),$$

where $\rho_i$ are identically and independently distributed across firms.

In addition to their private signal about the cost-push shock, firms get a signal on the monetary instrument.[10] The information conveyed by the central bank's disclosure depends upon its degree of transparency with respect to its monetary instrument. Each firm $i$ receives a signal on the central bank assessment about the state of the economy that is written, for the sake of generality, as

$$D_i = D + \phi_i = u + \mu + \phi_i, \text{ with } \phi_i \sim N\big(0, \sigma_\phi^2\big),$$

where $\sigma_\phi^2$ captures the uncertainty surrounding the monetary instrument in the economy. We assume that the communication regime (or degree of transparency of the central bank) is exogenous.[11] Since firms are rational, they know the policy coefficient $\nu$ and can infer the instrument implemented by the central bank from their signal on its economic assessment. When the central bank is transparent, all firms perfectly infer the true instrument (i.e., $\sigma_\phi^2 \to 0$) and it becomes common knowledge among them. By contrast, under opacity (i.e., $\sigma_\phi^2 \to \infty$), the central bank's disclosure does not contain any valuable information. This increases the uncertainty of firms about the instrument.

[10]This feature is empirically well documented by Romer and Romer (2000).

[11]A normative analysis of welfare goes beyond the scope of this paper. This paper simply aims at showing that the optimal response to cost-push shocks depends upon the disclosure regime of the central bank. When the central bank directly discloses its economic assessment, the signaling role of its monetary instrument becomes redundant, which allows to abstract from considering strategic distortions of the instrument.

Historically, central banks used to be extremely opaque and recently have become more and more transparent about their instrument. For example, before February 1994, the Federal Reserve did not publicly report on the federal funds rate it was targeting. In this context, the private sector had to infer the policy decisions of the Federal Open Market Committee from the market operations conducted by the trading desk of the Federal Reserve. This lack of transparency was a source of fundamental uncertainty about the rate targeted by the Federal Reserve and of strategic uncertainty about the beliefs of others about this target.

### *4.2 Equilibrium*

To determine the perfect Bayesian equilibrium behavior of firms, we recall the optimal pricing rule (2) for convenience and substitute successively the average price level with higher-order expectations about the cost-push shock and the monetary instrument:

$$\begin{aligned} p_i &= \mathbb{E}_i[(1-\xi)p + u + \xi I] \\ &= \mathbb{E}_i\left[u + \xi I + (1-\xi)\left[\bar{\mathbb{E}}\left[u + \xi I + (1-\xi)\left[\bar{\mathbb{E}}[u + \xi I + \ldots]\right]\right]\right]\right]. \end{aligned}$$

We denote by $E_i(.)$ the expectation operator of firm $i$ conditional on its information and by $\bar{\mathbb{E}}(.)$ the average expectation operator such that $\bar{\mathbb{E}}(.) = \int_i E_i(.)di$. With heterogeneous information, the law of iterated expectations fails since expectations of higher order do not collapse to the average expectation of degree one.[12] Thus, we rewrite the pricing rule as

$$p_i = \sum_{k=0}^{\infty}(1-\xi)^k \mathbb{E}_i[\bar{\mathbb{E}}^{(k)}(u + \xi I)],$$

and averaging over firms yields

$$p = \sum_{k=0}^{\infty}(1-\xi)^k [\bar{\mathbb{E}}^{(k+1)}(u + \xi I)], \tag{6}$$

[12]See Morris and Shin (2002).

where $\bar{\mathbb{E}}^{(k)}$ stands for the higher-order expectation of degree $k$. We use the following notation of higher-order expectations: $\bar{\mathbb{E}}^{(0)}(x) = x$ is the expected variable $x$ itself, $\bar{\mathbb{E}}^{(1)}(x) = \bar{\mathbb{E}}(x)$ is the average expectation of $x$, $\bar{\mathbb{E}}^{(2)}(x) = \bar{\mathbb{E}}\bar{\mathbb{E}}^{(1)}(x) = \bar{\mathbb{E}}\bar{\mathbb{E}}(x)$ is the average expectation of the average expectation of $x$, and so on.

In order to solve the inference problem of each firm

$$\mathbb{E}_i(u, I) = \mathbb{E}[u, I | u_i, D_i],$$

we define from the formula for conditional expectations of jointly normal random variables the corresponding covariance matrix $\mathbf{V}_{4\times 4}$ and the relevant submatrices

$$\mathbf{V} = \begin{pmatrix} \mathbf{V_{uu}} & \mathbf{V_{uo}} \\ \mathbf{V_{uo}^T} & \mathbf{V_{oo}} \end{pmatrix},$$

where $\mathbf{V_{uu}}$ is the covariance matrix for unobservable $(u,\ I)$ variables, $\mathbf{V_{uo}}$ the covariance matrix between unobservable $(u,\ I)$ and observable $(u_i,\ D_i)$ variables, and $\mathbf{V_{oo}}$ the covariance matrix for observable $(u_i,\ D_i)$ variables. The expectation of both the cost-push shock and the instrument conditional on the information set of firm $i$ is given by

$$\mathbb{E}\left(\begin{matrix} u \\ I \end{matrix} \middle| \; u_i, D_i\right) = \mathbf{\Omega}\begin{pmatrix} u_i \\ D_i \end{pmatrix} = \begin{pmatrix} \Omega_{11} & \Omega_{12} \\ \Omega_{21} & \Omega_{22} \end{pmatrix}\begin{pmatrix} u_i \\ D_i \end{pmatrix}$$
$$= \begin{pmatrix} \frac{\sigma_u^2\sigma_\mu^2+\sigma_u^2\sigma_\phi^2}{\sigma_u^2\sigma_\mu^2+\sigma_u^2\sigma_\rho^2+\sigma_u^2\sigma_\phi^2+\sigma_\mu^2\sigma_\rho^2+\sigma_\rho^2\sigma_\phi^2} & \frac{\sigma_u^2\sigma_\rho^2}{\sigma_u^2\sigma_\mu^2+\sigma_u^2\sigma_\rho^2+\sigma_u^2\sigma_\phi^2+\sigma_\mu^2\sigma_\rho^2+\sigma_\rho^2\sigma_\phi^2} \\ \frac{\nu\sigma_u^2\sigma_\phi^2}{\sigma_u^2\sigma_\mu^2+\sigma_u^2\sigma_\rho^2+\sigma_u^2\sigma_\phi^2+\sigma_\mu^2\sigma_\rho^2+\sigma_\rho^2\sigma_\phi^2} & \frac{\nu(\sigma_u^2\sigma_\mu^2+\sigma_u^2\sigma_\rho^2+\sigma_\mu^2\sigma_\rho^2)}{\sigma_u^2\sigma_\mu^2+\sigma_u^2\sigma_\rho^2+\sigma_u^2\sigma_\phi^2+\sigma_\mu^2\sigma_\rho^2+\sigma_\rho^2\sigma_\phi^2} \end{pmatrix}$$
$$\times \begin{pmatrix} u_i \\ D_i \end{pmatrix}, \quad (7)$$

where $\mathbf{\Omega} = \mathbf{V_{uo}}\mathbf{V_{oo}^{-1}}$.

We express the price equation (6) as

$$p = \sum_{k=0}^{\infty}(1-\xi)^k \left[(1\ \ \xi)\mathbf{\Omega}\mathbf{\Xi}^k \begin{pmatrix} u \\ D \end{pmatrix}\right],$$

where the matrix $\boldsymbol{\Xi}$ is given by the first-order expectation of the cost-push shock $u$ and the average central bank disclosure $D$:

$$\mathbb{E}\begin{pmatrix} u \\ D \end{pmatrix} \left| \; u_i, D_i \right) = \boldsymbol{\Xi} \begin{pmatrix} u_i \\ D_i \end{pmatrix} = \begin{pmatrix} \Omega_{11} & \Omega_{12} \\ \frac{1}{\nu}\Omega_{21} & \frac{1}{\nu}\Omega_{22} \end{pmatrix} \begin{pmatrix} u_i \\ D_i \end{pmatrix}.$$

The perfect Bayesian equilibrium yields the linear price setting of firm $i$ (see the appendix for the derivation of optimal coefficients):

$$\begin{aligned} p_i &= \gamma_1 u_i + \gamma_2 D_i \qquad \text{with} \\ \gamma_1 &= \frac{\frac{(1-\xi)}{\nu}\gamma_2 \Omega_{21} + \Omega_{11} + \xi\Omega_{21}}{1-(1-\xi)\Omega_{11}} \\ \gamma_2 &= \frac{(1-\xi)\gamma_1\Omega_{12} + \Omega_{12} + \xi\Omega_{22}}{1-\frac{(1-\xi)}{\nu}\Omega_{22}}. \end{aligned} \tag{8}$$

The optimal monetary policy consists of choosing the instrument (5) that minimizes the loss (3) subject to the price rule (8).

According to (3), the central bank minimizes the unconditional expected loss:

$$\mathbb{E}(L) = \operatorname{var}(p) + \lambda \cdot \operatorname{var}(y). \tag{9}$$

The optimal monetary policy will depend on the degree of the central bank's transparency. We derive the optimal monetary policy first under opacity and then under transparency.

### *4.3 Optimal Monetary Policy under Opacity*

Under opacity ($\sigma_\phi^2 \to \infty$), firms do not observe the monetary instrument. They are, however, aware that the central bank responds to cost-push shocks according to its information, and they rationally use their private information $u_i$ to infer the monetary instrument $I$.

In that case, the second column of $\boldsymbol{\Omega}$ in (7) consists of zeros, as the central bank's disclosure does not contain any valuable information. The solution to the inference problem of each firm boils down to

$$\mathbb{E}_i(u, I) = \mathbb{E}\begin{pmatrix} u \\ I \end{pmatrix} \left| \; u_i \right) = \begin{pmatrix} \Omega_1 \\ \Omega_2 \end{pmatrix} u_i = \begin{pmatrix} \frac{\sigma_u^2}{\sigma_u^2+\sigma_\rho^2} \\ \frac{\nu\sigma_u^2}{\sigma_u^2+\sigma_\rho^2} \end{pmatrix} u_i.$$

Plugging this into equation (6) yields

$$p = \sum_{k=0}^{\infty}(1-\xi)^k \left[\Omega_1^{k+1}(1+\xi\nu)u\right]$$
$$= \frac{\Omega_1(1+\xi\nu)}{1-(1-\xi)\Omega_1}u = \frac{\sigma_u^2}{\sigma_\rho^2+\xi\sigma_u^2}(1+\xi\nu)u = \gamma_1 u. \qquad (10)$$

The optimal monetary policy consists of choosing the instrument (5) that minimizes the unconditional expected loss (9) subject to the price rule (10). The variance of the price level is simply given by

$$\mathrm{var}(p) = \gamma_1^2\sigma_u^2,$$

while the variance of the output gap is

$$\mathrm{var}(y) = (\nu-\gamma_1)^2\sigma_u^2 + \nu^2\sigma_\mu^2.$$

The fixed-point solution to this optimization problem yields the following equilibrium price setting for firm $i$:

$$p_i = \gamma_1 u_i$$
$$= \frac{\lambda\sigma_u^2}{\xi\sigma_u^2+\sigma_\rho^2}\cdot\frac{\sigma_u^2\sigma_\rho^4+\xi^2\sigma_u^4\sigma_\mu^2+2\xi\sigma_u^2\sigma_\rho^2\sigma_\mu^2+\sigma_\rho^4\sigma_\mu^2+\xi\sigma_u^4\sigma_\rho^2}{\xi^2\sigma_u^6+\lambda\sigma_u^2\sigma_\rho^4+\lambda\xi^2\sigma_u^4\sigma_\mu^2+2\lambda\xi\sigma_u^2\sigma_\rho^2\sigma_\mu^2+\lambda\sigma_\rho^4\sigma_\mu^2}u_i,$$

while the optimal monetary policy satisfies

$$\nu = \frac{\lambda\sigma_u^4\sigma_\rho^2-\xi\sigma_u^6}{\xi^2\sigma_u^6+\lambda\sigma_u^2\sigma_\rho^4+\lambda\xi^2\sigma_u^4\sigma_\mu^2+2\lambda\xi\sigma_u^2\sigma_\rho^2\sigma_\mu^2+\lambda\sigma_\rho^4\sigma_\mu^2}. \qquad (11)$$

Interestingly, under opacity, the optimal monetary policy coefficient (11) can be positive or negative depending on the parameter configuration. As discussed above, cost-push shocks create a trade-off between price and output-gap stabilization. The central bank disclosure influences the reaction of the price level to monetary policy and thereby the trade-off the central bank faces. Opacity reduces the effectiveness of monetary policy on the price level as it increases fundamental and strategic uncertainty of firms about the central bank's action. Under opacity, the central bank's influence on the price level is limited, as firms do not observe its instrument. So, contracting the aggregate demand is ineffective to reduce the price level and the central bank may find it optimal to reduce the negative output gap (instead of the price level) by increasing aggregate demand (i.e., $\nu > 0$).

Yet opacity is not a sufficient condition for monetary policy to be accommodative. The sign of the policy coefficient (11) depends on the relation between the degree of strategic complementarities $1-\xi$, the preference of the central bank for output-gap stabilization $\lambda$, and the relative precision of firm's information $\sigma_\rho^2/\sigma_u^2$. In particular, the following condition holds:

$$\nu > 0 \Leftrightarrow \xi < \lambda \frac{\sigma_\rho^2}{\sigma_u^2}. \tag{12}$$

We propose to call the case where $\nu > 0$ the *blow with the wind* policy, according to which the central bank expands nominal aggregate demand whenever cost-push shocks are positive. We now discuss the conditions for $\nu > 0$.

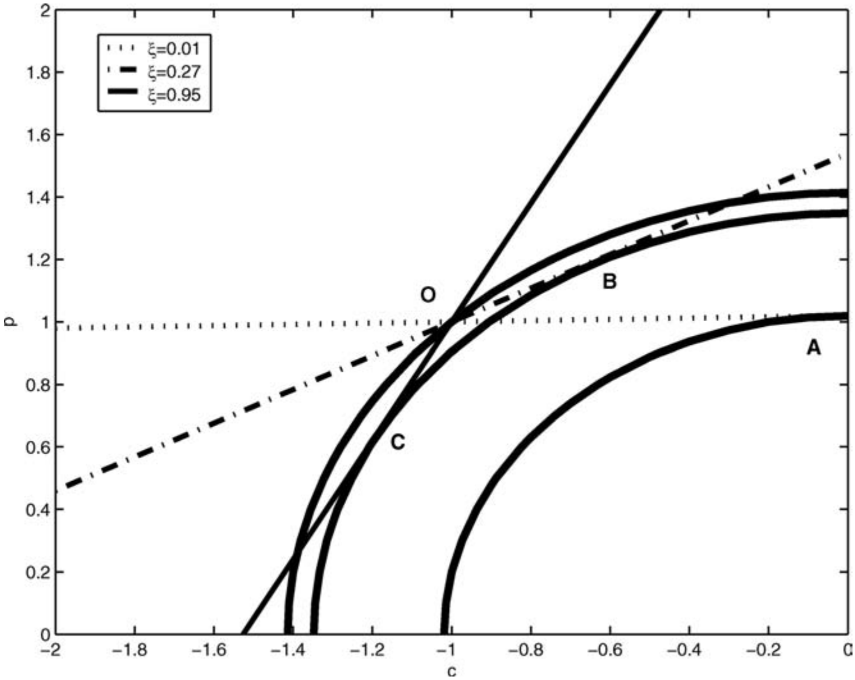
#### *4.3.1 Degree of Strategic Complementarities*

The policy coefficient is positive when complementarities are high ($\xi$ low). As opacity alleviates the effectiveness of monetary policy on the price level, strong complementarities reduce it even further. When the degree of strategic complementarities in the economy is high, higher-order expectations are given an increasing weight in the price setting. This exacerbates strategic uncertainty about the monetary instrument that characterizes opacity and reduces the effectiveness of monetary policy to stabilize the price level. This renders price-level stabilization ineffective compared with output-gap stabilization, and the central bank then faces a trade-off that incites it to stabilize the output gap rather than the price level (i.e., $\nu > 0$).

#### *4.3.2 Precision of Private Information*

When the relative precision of firms' private information increases ($\sigma_\rho^2/\sigma_u^2$ falls), fundamental and strategic uncertainty of firms about the monetary instrument decreases. The reduction of uncertainty renders monetary policy more effective to stabilize the price level,

**Figure 1. Phillips Curves and Economic Outcomes under Opacity: Impact of Strategic Complementarities**




and the trade-off favors leaning against the wind. This increases the incentive of the central bank to reduce price deviation. Firms also respond more strongly to cost-push shocks with more accurate information. This implies that the strength of the central bank's response increases: the absolute value of the policy coefficient rises.

#### *4.3.3 Central Bank's Preference*

Finally, when the central bank is more inclined toward price stabilization, the incentive of the central bank to contract the nominal demand in order to reduce the price level increases in a very intuitive way. Then leaning against the wind is preferred to blowing with the wind.

We can now interpret former monetary policy issues in terms of Phillips curves, as shown in figure 1. The latter describe the price-output combinations the central bank can achieve with its policy. Since the degree of transparency drives the effectiveness of monetary policy to stabilize prices, it also shapes the slope of Phillips curves. Figure 1 is computed with $\sigma_\mu^2 = \sigma_\rho^2 = \sigma_u^2/2$ and $\lambda = 1$ ($\sigma_\phi^2 \to \infty$ under opacity) for three levels of strategic complementarities. As opacity enhances uncertainty about the monetary instrument, its effectiveness is driven by the degree of strategic complementarities $1 - \xi$ and the precision of firms' information $\sigma_\rho^2/\sigma_u^2$. More particularly, when complementarities are extremely strong or the precision of firms' information is nearly zero ($\xi \to 0$ or $\sigma_\rho^2 \to \infty$), the effectiveness of monetary policy on prices is highly limited and the corresponding Phillips curve is horizontal (dotted line). Suppose that the economic outcome in the absence of central bank intervention is written as O. When the central bank is opaque, the degree of complementarities relatively strong, and firms' information not too accurate, condition (12) says that the optimal monetary policy is expansive. The resulting economic outcomes are written as A and B in figure 1. Reducing complementarities or increasing precision of firms' information reduces uncertainty (or its impact) and raises the slope of the Phillips curve under opacity (dashed line and solid line in figure 1). When firms' information is very accurate ($\sigma_\rho^2 \to 0$), the curve is vertical. The slope of the Phillips curve determines whether the monetary policy is expansive (points A and B) or contractive (point C).

### *4.4 Optimal Monetary Policy under Transparency*

This section derives the optimal monetary policy when the monetary instrument is common knowledge among firms. In the case of full transparency ($\sigma_\phi^2 = 0$), the solution to the inference problem of firm $i$ is given by

$$
\begin{aligned}
\mathbb{E}\left(\begin{matrix} u \\ I \end{matrix} \,\middle|\, u_i, D\right) &= \begin{pmatrix} \Omega_{11} & \Omega_{12} \\ \Omega_{21} & \Omega_{22} \end{pmatrix} \begin{pmatrix} u_i \\ D \end{pmatrix} \\
&= \begin{pmatrix} \frac{\sigma_u^2\sigma_\mu^2}{\sigma_u^2\sigma_\mu^2+\sigma_u^2\sigma_\rho^2+\sigma_\rho^2\sigma_\mu^2} & \frac{\sigma_u^2\sigma_\rho^2}{\sigma_u^2\sigma_\mu^2+\sigma_u^2\sigma_\rho^2+\sigma_\rho^2\sigma_\mu^2} \\ 0 & \nu \end{pmatrix} \begin{pmatrix} u_i \\ D \end{pmatrix}.
\end{aligned}
$$

The equilibrium pricing rule (8) is described by

$$p_i = \frac{\sigma_u^2\sigma_\mu^2}{\xi\sigma_u^2\sigma_\mu^2 + \sigma_u^2\sigma_\rho^2 + \sigma_\mu^2\sigma_\rho^2} u_i + \left[\frac{\sigma_u^2\sigma_\rho^2}{\xi\left(\xi\sigma_u^2\sigma_\mu^2 + \sigma_u^2\sigma_\rho^2 + \sigma_\mu^2\sigma_\rho^2\right)} + \nu\right] D. \tag{13}$$

Minimizing the unconditional expected loss (9) subject to firms' pricing rule (13) yields the following optimal monetary policy:

$$\nu = -\frac{1}{\xi}\frac{\sigma_u^2}{\sigma_u^2 + \sigma_\mu^2} < 0.$$

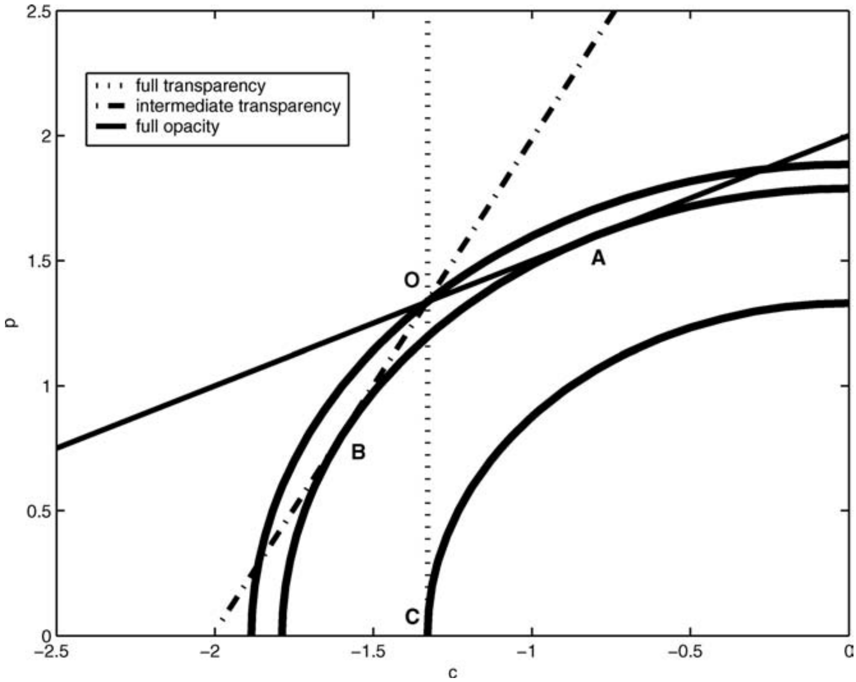
The optimal policy under transparency coincides with the standard monetary policy analysis consisting in leaning against the wind. Indeed, standard literature assumes that the instrument is common knowledge among firms (firms know the monetary instrument implemented by the central bank) but appears as a particular case in our framework (i.e., transparency case).

### *4.5 Increase in Central Bank Transparency*

While the former analysis is restricted to extreme disclosure strategies (i.e., opacity vs. transparency), the current section discusses the case of intermediate levels of transparency ($0 < \sigma_\phi^2 < \infty$). More particularly, we examine the impact of an increase in transparency of the central bank's monetary instrument on the optimal monetary policy. We show that small variations in transparency or in the central bank's preferences can have large effects on the optimal conduct of monetary policy.

Figure 2 illustrates the economic outcome for different degrees of transparency. The parameter values are $\sigma_\mu^2 = \sigma_\rho^2 = \sigma_u^2/2$, $\xi = 0.25$, and $\lambda = 1$. The dotted line represents the possible price-output combinations for a fully transparent central bank. In this case, since monetary policy is common knowledge among firms, the Phillips curve is vertical. The solid line is the Phillips curve for full opacity. The dashed line represents an intermediate degree of transparency. The slope of the curve falls with strategic complementarities and rises with the precision of firms' private information and with the degree of transparency. Under opacity and when the curve is relatively flat, the optimal monetary policy is expansive and leads to the

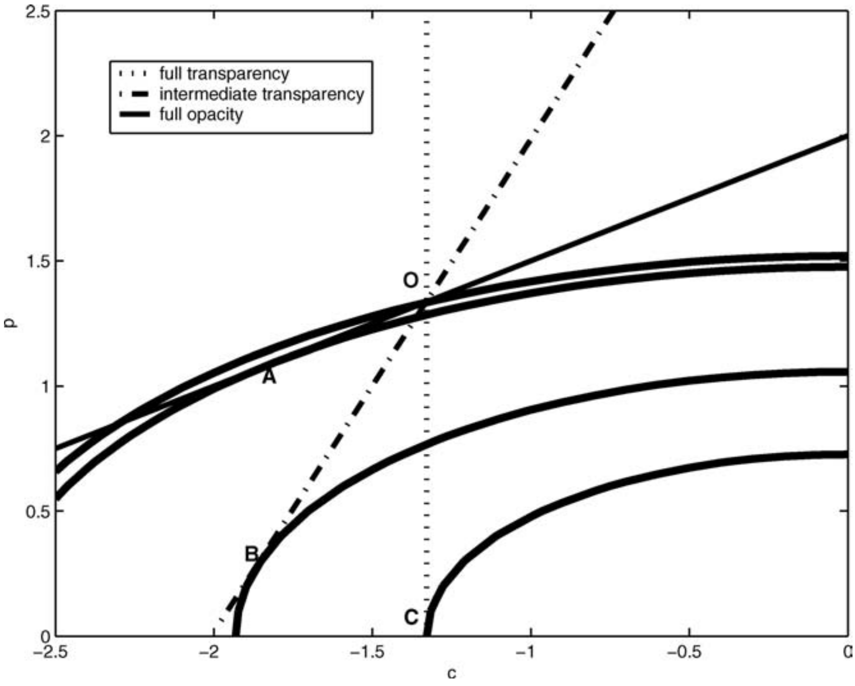
**Figure 2. Phillips Curves and Economic Outcomes: Impact of Transparency ($\boldsymbol{\lambda = 1}$)**




economic outcome indicated by point A. Interestingly, this analysis suggests that a central bank acting under opacity and choosing the economic outcome written A goes for the blow against the wind policy: while inflation expectations rise because of a positive cost-push shock, the central bank expands nominal aggregate demand, which exacerbates the rise in inflation. Econometricians examining such time series would conclude, as do Clarida, Galí, and Gertler (2000) for the 1970s, that the central bank is accommodative. By contrast, when transparency increases or when complementarities weaken or when firms' information is more accurate, the Phillips curve becomes steeper. This yields a contractive optimal monetary policy (point B). Finally, with full transparency, the policy is always contractive and the outcome is given by C.

Figure 3 illustrates the case where the central bank is more inclined toward price stabilization. The parameter values are $\sigma_\mu^2 =$

**Figure 3. Phillips Curves and Economic Outcomes: Impact of Transparency ($\boldsymbol{\lambda = 0.3}$)**




$\sigma_\rho^2 = \sigma_u^2/2$, $\xi = 0.25$, and $\lambda = 0.3$. The optimal monetary policy may be restrictive even for an opaque central bank. Point A shows the outcome resulting from a contractive monetary policy.

## 5. Concluding Remarks

Our model highlights the relevance of a central bank's disclosure for the effectiveness of monetary policy in an economy characterized by strategic complementarities and heterogeneous information. The high inflation of the 1970s is usually rationalized within the Barro-Gordon framework. This literature presumes that the high-inflation episode comes from the incentive of the central bank to push the output above its natural level and to cheat the private sector. In this context, most of the literature has called for transparency in order to achieve credibility. In contrast, we show that, even in the absence of an inflationary bias, a credible central bank may find it optimal to accommodate monetary policy in response to a cost-push shock whenever the uncertainty surrounding its monetary instrument is high. In particular, central bank opacity linked to some preference for output-gap stabilization yields an optimal monetary policy that accommodates a cost-push shock. As the central bank faces a trade-off between price and output-gap stabilization, its disclosure influences the effectiveness of its policy and thus whether it will focus on price or on output-gap stabilization. An accommodating policy can be attributed to the lack of transparency and not necessarily to the lack of credibility. Second, our analysis highlights the fact that transparency is not just a means to enhance central bank credibility but also plays a crucial role in the optimality of monetary policy implemented by a fully credible central bank.

## Appendix. Linear Pricing Rule

This appendix solves the perfect Bayesian equilibrium for the pricing rule of firms given by equation (8).

We first postulate, as in Morris and Shin (2002), that the optimal price of firm $i$ is a linear combination of its two signals:

$$p_i = \gamma_1 u_i + \gamma_2 D_i. \tag{14}$$

The optimal weights $\gamma_1$ and $\gamma_2$ depend on firms' expectations about the pricing behavior of other firms. The conditional estimate of the average price is therefore given by

$$\mathbb{E}_i(p) = \gamma_1 \mathbb{E}_i(u) + \gamma_2 \mathbb{E}_i(D). \tag{15}$$

Plugging $E_i(p)$ into the pricing rule (2) and replacing the expectations of firm $i$ about $u$, $D$, and $I$ yields

$$\begin{aligned}
p_i &= \mathbb{E}_i[(1-\xi)p + u + \xi I] \\
&= (1-\xi)[\gamma_1 \mathbb{E}_i(u) + \gamma_2 \mathbb{E}_i(D)] + \mathbb{E}_i(u) + \xi \mathbb{E}_i(I) \\
&= (1-\xi)\left[\gamma_1(\Omega_{11}u_i + \Omega_{12}D_i) + \gamma_2\left(\frac{\Omega_{21}}{\nu}u_i + \frac{\Omega_{22}}{\nu}D_i\right)\right] \\
&\quad + \Omega_{11}u_i + \Omega_{12}D_i + \xi\Omega_{21}u_i + \xi\Omega_{22}D_i.
\end{aligned}$$

Rearranging gives

$$p_i = u_i \left[ (1-\xi) \left( \gamma_1 \Omega_{11} + \gamma_2 \frac{\Omega_{21}}{\nu} \right) + \Omega_{11} + \xi \Omega_{21} \right]$$
$$+ D_i \left[ (1-\xi) \left( \gamma_1 \Omega_{12} + \gamma_2 \frac{\Omega_{22}}{\nu} \right) + \Omega_{12} + \xi \Omega_{22} \right].$$

Identifying the coefficients, we get

$$\gamma_1 = \frac{\frac{(1-\xi)}{\nu} \gamma_2 \Omega_{21} + \Omega_{11} + \xi \Omega_{21}}{1 - (1-\xi)\Omega_{11}}$$
$$\gamma_2 = \frac{(1-\xi)\gamma_1 \Omega_{12} + \Omega_{12} + \xi \Omega_{22}}{1 - \frac{(1-\xi)}{\nu} \Omega_{22}}.$$

This system of equations is equivalent to (8) in the main text.

## References


Adam, K. 2007. "Optimal Monetary Policy with Imperfect Common Knowledge." *Journal of Monetary Economics* 54 (2): 267–301.

Baeriswyl, R., and C. Cornand. 2006. "Monetary Policy and Its Informative Value." FMG Discussion Paper No. 569, London School of Economics (July).

Clarida, R., J. Galí, and M. Gertler. 1999. "The Science of Monetary Policy: A New Keynesian Perspective." *Journal of Economic Literature* 37 (4): 1661–1707.

———. 2000. "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory." *Quarterly Journal of Economics* 115 (1): 147–80.

De Long, J. B. 1997. "America's Peacetime Inflation: The 1970s." In *Reducing Inflation: Motivation and Strategy*, ed. C. Romer and D. Romer. Chicago: University of Chicago Press.

Demiralp, S., and O. Jordà. 2002. "The Announcement Effect: Evidence from Open Market Desk Data." *Economic Policy Review* (Federal Reserve Bank of New York) 8 (1): 29–48.

Dincer, N., and B. Eichengreen. 2006. "Central Bank Transparency: Where, Why, and to What Effect?" Mimeo. Available at http://www.centrecournot.org/pdf/conference9/Barry%20EICHENGREEN.pdf.

Eijffinger, S. C. W., and P. M. Geraats. 2006. "How Transparent Are Central Banks?" *European Journal of Political Economy* 22 (1): 1–21.

Geraats, P. M. 2002. "Central Bank Transparency." *The Economic Journal* 112 (483): F532–65.

Goodfriend, M., and R. G. King. 2005. "The Incredible Volcker Disinflation." *Journal of Monetary Economics* 52 (5): 981–1015.

Hellwig, C. 2002. "Public Announcements, Adjustment Delays and the Business Cycle." Mimeo. Available at http://www.econ.ucla.edu/people/papers/Hellwig/Hellwig208.pdf.

Mankiw, N. G., and R. Reis. 2002. "Sticky Information versus Sticky Prices: A Proposal to Replace the New Keynesian Phillips Curve." *Quarterly Journal of Economics* 117 (4): 1295–1328.

Morris, S., and H. S. Shin. 2002. "Social Value of Public Information." *American Economic Review* 92 (5): 1521–34.

Orphanides, A. 2005. "Comment on: 'The Incredible Volcker Disinflation'." *Journal of Monetary Economics* 52 (5): 1017–23.

Romer, C. D., and D. H. Romer. 2000. "Federal Reserve Information and the Behavior of Interest Rates." *American Economic Review* 90 (3): 429–57.

Schwartz, A. J. 2003. "Comment on: Historical Monetary Policy Analysis and the Taylor Rule." *Journal of Monetary Economics* 50 (5): 1023–27.

Walsh, C. E. 2006. "Transparency, Flexibility, and Inflation Targeting." In *Monetary Policy under Inflation Targeting*, ed. F. Mishkin and K. Schmidt-Hebbel. Santiago, Chile: Central Bank of Chile.

———. 2007. "Optimal Economic Transparency." *International Journal of Central Banking* 3 (1): 5–36.

Woodford, M. 2003. "Imperfect Common Knowledge and the Effects of Monetary Policy." In *Knowledge, Information and Expectations in Modern Macroeconomics: In Honor of Edmund S. Phelps*, ed. P. Aghion, R. Frydman, J. Stiglitz, and M. Woodford. Princeton, NJ: Princeton University Press.