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Can Opacity of a Credible Central Bank Explain Excessive Inflation?*

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Abstract

Excessive inflation is usually attributed to the lack of central bank's credibility. In this context, most of the literature considers transparency a means to establish central bank's credibility. The contribution of this paper is twofold. First, it shows that, even in the absence of inflationary bias, a credible central bank may find it optimal to implement an accommodating monetary policy in response to cost-push shocks whenever the uncertainty surrounding its monetary instrument is high. Indeed, the degree of central bank's transparency influences the effectiveness of its policy to stabilize inflation in terms of output gap, and thereby whether it will implement an expansionary or contractionary policy in response to cost-push shocks. Second, it stresses that transparency is not just a means to achieve credibility but is essential *per se* for the optimality of monetary policy of a fully credible central bank.

JEL classification: E58, E52, D82.
Keywords: differential information, monetary policy, transparency, cost-push shocks.

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1 Introduction

Excessive inflation rates that clearly exceed the rate that seems to be socially desirable are generally viewed as the most dramatic failure of the conduct of monetary policy in the second half of the twentieth century. This feature has been usually explained within the framework of Barro and Gordon (1983), which presumes that the central bank desires to push the output above its natural level. Indeed, under discretion, the central bank's incentive to boost the output above its potential level gives rise to a persistent inflationary bias that supports the monetary outcome of the last decades.
Yet, the inflationary bias argument is a matter of controversy. Three strands of criticism have been developed. First, Taylor (1983) and McCallum (1997) question the plausibility of the inflationary bias argument since any rational central bank should recognize that the renouncement to cheat the private sector yields a superior outcome. In its comment to Barro and Gordon (1983), Taylor (p. 125) writes that "*[. . .] the superiority of the zero inflation policy is obvious [. . .]. It is therefore difficult to see why the zero inflation policy would not be adopted*" by the central bank. Second, Blinder (1998) (p. 40) points out the particular economic context of high inflation episodes in the 1970s and argues that "*Barro and Gordon ignored the obvious practical explanations for the observed upsurge in inflation – the Vietnam War, the end of the Bretton-Woods system, two OPEC shocks, and so on – and sought instead a theoretical explanation for what they believed to be a systematic inflationary bias in the behaviour of central banks*". And third, as the Barro-Gordon literature calls for institutional changes in order to cope with inflation, Friedman and Kuttner (1996) (p. 79) emphasize that "*not only have most countries succeeded in slowing their economy's inflation, in most cases they have done so under monetary policymaking institutions no different than they had before*".
The first aim of this paper is to provide an alternative explanation to the time-inconsistency literature for high inflation episodes that is consistent with the three aforesaid criticisms.[1] We show that the optimal monetary policy is a function of the central bank's disclosure regime. As a result, central bank's opacity can account for an expansive monetary policy in response to oil shocks, even when the central bank is fully credible. This sharply contrasts with the standard monetary policy literature that calls – according to the *lean against the wind* principle – for taking a restrictive action whenever inflation is above target.[2]

[1] Orphanides (2002) alternatively argues that policy decisions during the 70s can be reconciled with an optimal approach accounting for the errors in the real time assessments of the natural rate of unemployment by the Fed.

[2] Note that some authors adopt other definitions of the *lean against the wind* principle. 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 et al. (1999) (p. 1672) say that "*the central bank pursues a 'lean*

So, the lack of central bank's credibility is not a necessary condition for excessive inflation. Opacity of a credible central bank supports a monetary policy that violates the *lean against the wind* principle when the economy is affected by cost-push shocks.

The second aim of this paper is to stress that transparency is not just a means to establish the credibility of the central bank but is essential in itself for the optimality of monetary policy implemented by a fully credible central bank. While standard literature emphasizes the relevance of transparency for achieving credibility in central banking, we underline that transparency also plays a crucial role in the case of a fully credible central bank. Moreover, the lack of transparency of a credible central bank can account for monetary phenomena that are often attributed to the lack of credibility.

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. As cost-push shocks create a trade-off between price and output gap stabilization, the central bank may find it optimal to stabilize rather the output gap than the price level when its policy is relatively ineffective to influence the price level, *i.e.* when the central bank is opaque with respect to its policy.

In an empirical analysis on US data, Romer and Romer (2000) show that the observation of the monetary instrument highly influences the formation of market expectations. Moreover, Demiralp and Jorda (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 Fed since 1994 has increased the effectiveness of monetary policy to shape market expectations (announcement effect).

We propose a monetary policy model under monopolistic competition with imperfect common knowledge on the cost-push shocks affecting the economy where the central bank has no inflationary bias and the private sector perfectly knows its preferences. Both the central bank and firms are uncertain about the true state of the economy and receive private signals on cost-push shocks. Firms also get some signal on the monetary instrument of the central bank according to the degree of transparency of the central bank with respect to its policy. As the central bank's disclosure does not contain any valuable information under opacity, the monetary instrument is common knowledge among firms under transparency.

The mechanism of the model is the following. The information disclosed by the

against the wind' policy: Whenever inflation is above target, contract demand below capacity (by raising the interest rate)."

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, the optimal monetary policy always satisfies the *lean against the wind* principle. By contrast, opacity increases fundamental and strategic uncertainty about the central bank's action and thereby reduces the effectiveness of monetary policy on the price level. Under opacity, the central bank's influence on the price level is limited as firms do not observe its instrument. So, contracting the nominal demand is ineffective to reduce the price level and the central bank may find it optimal to reduce the output gap by expanding its instrument.[3] This rationalizes the finding of Clarida et al. (2000) according to which the Federal Reserve was highly accommodative in the pre-Volcker years. But opacity is not a sufficient condition for the optimal monetary policy to be accommodating. The sign of the policy coefficient depends on the relation between the degree of strategic complementarities, the preference of the central bank for output-gap stabilization, and the relative precision of firms' private information.

The three strands of criticism raised against the Barro-Gordon model do not apply to our argument. First, our central bank does not have an incentive to push output above its potential level. Second, our model accounts for the response of monetary policy to cost-push shocks. And third, as no significant institutional changes occurred in the central bank of most OECD countries, the switch from opacity to transparency is an obvious development in the recent conduct of monetary policy that accounts for the decrease in inflation.

The remaining of the 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 perfect common knowledge that recalls standard findings in monetary policy analysis and gives useful insights for the intuition behind our main result. Section 4 examines the case of imperfect common knowledge and shows that the optimal monetary policy under opacity may violate the *lean against the wind* principle. 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.

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

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

2.1 Firms

The behavior of firms consists in choosing a price. Under monopolistic competition *a la* Dixit-Stiglitz, firms set their price as a function of their expectations of the overall price level p, the real output gap c, and the cost-push shock u.[4] One can show that the optimal price of firm i is given by

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

The pricing rule (1) captures the strategic complementarities of prices. Indeed, each firm i sets its price according to its expectation about both fundamentals (the output gap c and the cost-push shock u) and the average action of others, the overall price level p.

The parameter ξ 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. Using the fact that the nominal aggregate demand (deviation) y is by definition equal to $c + p$, we rewrite the pricing rule (1) as

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

In the whole paper, we realistically assume that prices are strategic complements and impose $0 < \xi \leq 1$. When ξ decreases, the optimal price setting responds less strongly to fundamentals (y 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, imperfect common knowledge among firms may account for nonneutral 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.

[4] For the microfounded derivation, see Adam (2006) or Woodford (2003).

2.2 Central bank

The central bank minimizes the deviation of both the output gap c and the price level p from their respective target owing to its monetary instrument I. The central bank's optimization problem consists in minimizing its loss

$$L = \min_{I} \mathbb{E}_{cb}[\lambda c^2 + p^2] \tag{3}$$

where $c = y - p$ is the output gap and λ 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, we assume that the central bank directly controls nominal aggregate demand with its monetary instrument ($y = I$). So, the pricing rule (2) can be rewritten as

$$p_i = \mathbb{E}_i\big[(1-\xi)p + u + \xi I\big]. \tag{4}$$

Finally, the economy is affected by cost-push shocks that are normally distributed:

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

3 Perfect common knowledge

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

When information is perfect and common to all firms, every firm sets the same price ($p_i = p$). The pricing rule (4) 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 ξ is small, nominal aggregate demand is given a lower weight into the pricing rule, which increases the relative weight assigned to cost-push shocks.

The central bank chooses its instrument to minimize its loss (3). The monetary instrument is linear in central bank's information u_{cb}: $I = \nu u_{cb}$, where ν 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 monetary response to cost-push shocks is a particularly interesting issue since they cannot be neutralized by the central bank. Indeed, cost-push shocks create a trade-off between price level and output gap stabilization. In the absence of any monetary policy action, a positive cost-push shock raises the price level and generates a negative output gap. While price level stabilization calls for a contractionary policy, output gap stabilization requires an expansionary one. As we argue in this paper, whether the central bank will be involved in price or output gap stabilization depends on the effectiveness of monetary policy to stabilize prices.

The loss under perfect information can be written as

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

and minimizing it yields the following optimal monetary policy:

$$\nu \quad = \quad -\frac{1}{\xi}. \tag{5}$$

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 (5) is consistent with standard optimal monetary policy analysis.[5] The optimal monetary policy coefficient ν 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 a standard result in monetary policy and is known as the *lean against the wind* principle. 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 perfect common knowledge, 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 imperfect common knowledge among firms, optimal monetary policy may call for output gap stabilization.

[5] See Clarida et al. (1999) for an overview on standard New Keynesian monetary policy analysis.

4 Imperfect common knowledge

We now turn to the more realistic case where the state of the economy is imperfect common knowledge among firms because they have differential information. We apply the methodology of Morris and Shin (2002) to our framework of optimal monetary policy. The latter emphasize the relevance of public information in an economy characterized by strategic complementarities and imperfect common knowledge. The context of their analysis fits our framework particularly well as price setting of firms exhibits strategic complementarities and as the monetary policy is imperfect common knowledge among firms when the central bank is opaque with respect to its intrument.

4.1 Information structure

The information structure in the economy is as follows. 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:

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

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

$$I = \nu(u + \mu). \tag{6}$$

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:

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

where ρ_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.[6] 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

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

[6]Here our work relates to Walsh (2005), which considers that the monetary instrument is both an action and a vehicle for information. This feature is empirically well-documented by Romer and Romer (2000).

where σ_ϕ^2 is the degree of transparency. It captures the uncertainty surrounding the monetary instrument in the economy. Since firms are rational, they know the policy coefficient ν 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 observe 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.
Historically, central banks used to be extremely opaque and have become recently 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 Fed. This lack of transparency was a source of fundamental uncertainty about the rate targeted by the Fed 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 (4) for convenience and substitute successively the average price level with higher order expectations about the cost-push shock and the monetary instrument

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

We denote by $\mathbb{E}_i(.)$ the expectation operator of firm i conditional on its information and by $\bar{\mathbb{E}}(.)$ the average expectation operator such that $\bar{\mathbb{E}}(.) = \int_i \mathbb{E}_i(.)di$. With heterogeneous information, the law of iterated expectations fails and expectations of higher order do not collapse to the average expectation of degree one.[7] Thus, we rewrite the pricing rule as

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

[7] See Morris and Shin (2002).

and averaging over firms yields

$$p = \sum_{k=0}^{\infty} (1-\xi)^k \left[\bar{\mathbb{E}}^{(k+1)}(u + \xi I) \right], \tag{7}$$

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 the corresponding covariance matrix $\mathbf{V}_{4\times 4}$ and the relevant sub-matrices

$$\mathbf{V} \quad = \quad \begin{pmatrix} \mathbf{V_{uu}} & \mathbf{V_{uo}} \\ \mathbf{V_{ou}} & \mathbf{V_{oo}} \end{pmatrix}.$$

The expectation of both the cost-push shock and the instrument conditional on the information set of firm i is given by

$$\mathbb{E}\left(\begin{array}{c} u \\ I \end{array} \middle| \; u_i, D_i \right) = \mathbf{\Omega} \begin{pmatrix} u_i \\ D_i \end{pmatrix} = \begin{pmatrix} \Omega_{11} & \Omega_{12} \\ \Omega_{21} & \Omega_{22} \end{pmatrix} \begin{pmatrix} u_i \\ D_i \end{pmatrix} \tag{8}$$
$$= \begin{pmatrix} \frac{\sigma_u^2\sigma_\mu^2+\sigma_u^2\sigma_\phi^2}{\sigma_u^2\sigma_\mu^2+\sigma_u^2\sigma_\rho^2+\sigma_u^2\sigma_\phi^2+\sigma_\mu^2\sigma_\rho^2+\sigma_\rho^2\sigma_\phi^2} & \frac{\sigma_u^2\sigma_\rho^2}{\sigma_u^2\sigma_\mu^2+\sigma_u^2\sigma_\rho^2+\sigma_u^2\sigma_\phi^2+\sigma_\mu^2\sigma_\rho^2+\sigma_\rho^2\sigma_\phi^2} \\ \frac{\nu\sigma_u^2\sigma_\phi^2}{\sigma_u^2\sigma_\mu^2+\sigma_u^2\sigma_\rho^2+\sigma_u^2\sigma_\phi^2+\sigma_\mu^2\sigma_\rho^2+\sigma_\rho^2\sigma_\phi^2} & \frac{\nu(\sigma_u^2\sigma_\mu^2+\sigma_u^2\sigma_\rho^2+\sigma_\mu^2\sigma_\rho^2)}{\sigma_u^2\sigma_\mu^2+\sigma_u^2\sigma_\rho^2+\sigma_u^2\sigma_\phi^2+\sigma_\mu^2\sigma_\rho^2+\sigma_\rho^2\sigma_\phi^2} \end{pmatrix} \begin{pmatrix} u_i \\ D_i \end{pmatrix},$$

where $\mathbf{\Omega} = \mathbf{V_{uo}}\mathbf{V_{oo}^{-1}}$.
We express the price equation (7) as

$$p = \sum_{k=0}^{\infty} (1-\xi)^k \left[\begin{pmatrix} 1 & \xi \end{pmatrix} \mathbf{\Omega}\mathbf{\Xi}^k \begin{pmatrix} u \\ D \end{pmatrix} \right], \tag{9}$$

where the matrix Ξ is given by the first-order expectation of the cost-shock u and the average central bank disclosure D

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

The perfect Bayesian equilibrium yields the linear price setting of firm i

$$\begin{aligned} p_i &= \gamma_1 u_i + \gamma_2 D_i \qquad \text{with} \\ \gamma_1 &= \frac{\frac{(1-\xi)}{\nu}\gamma_2\Omega_{21} + \Omega_{11} + \xi\Omega_{21}}{1-(1-\xi)\Omega_{11}} \\ \gamma_2 &= \frac{(1-\xi)\gamma_1\Omega_{12} + \Omega_{12} + \xi\Omega_{22}}{1-\frac{(1-\xi)}{\nu}\Omega_{22}}. \end{aligned} \tag{10}$$

The optimal monetary policy consists of choosing the instrument (6) that minimizes the loss (3) subject to the price rule (9).
According to (3), the central bank minimizes the unconditional expected loss

$$\mathbb{E}(L) = \text{var}(p) + \lambda \cdot \text{var}(c). \tag{11}$$

The variance of the price level is given by

$$\text{var}(p) = (\gamma_1 + \gamma_2)^2\sigma_u^2 + \gamma_2^2\sigma_\mu^2,$$

and the variance of the output gap is

$$\text{var}(c) = (\nu - \gamma_1 - \gamma_2)^2\sigma_u^2 + (\nu - \gamma_2)^2\sigma_\mu^2.$$

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

4.3 Optimal montary 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 rationally use their private information u_i to infer the monetary instrument I.
In that case, the second column of $\boldsymbol{\Omega}$ in (8) 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

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

Plugging this into equation (7) yields

$$\begin{aligned} p &= \sum_{k=0}^{\infty}(1-\xi)^k\left[\Omega_1^{k+1}(1+\xi\nu)u\right] \\ &= \frac{\Omega_1(1+\xi\nu)}{1-(1-\xi)\Omega_1}u = \frac{\sigma_u^2}{\sigma_\rho^2+\xi\sigma_u^2}(1+\xi\nu)u = \gamma_1 u. \end{aligned} \tag{12}$$

The optimal monetary policy consists of choosing the instrument (6) that minimizes the unconditional expected loss (11) subject to the price rule (12). The variance of the price level is simply given by

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

while the variance of the output gap is

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

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

$$\begin{aligned} \nu &= -\frac{(\xi\Omega_1^2-\lambda(1-\Omega_1)\Omega_1)\sigma_u^2}{(\xi^2\Omega_1^2+\lambda(1-\Omega_1)^2)\sigma_u^2+\lambda(1-(1-\xi)\Omega_1)^2\sigma_\mu^2} \\ &= \frac{\lambda\sigma_u^4\sigma_\rho^2-\xi\sigma_u^6}{\xi^2\sigma_u^6+\lambda\sigma_u^2\sigma_\rho^4+\lambda\xi^2\sigma_u^4\sigma_\mu^2+2\lambda\xi\sigma_u^2\sigma_\rho^2\sigma_\mu^2+\lambda\sigma_\rho^4\sigma_\mu^2}. \end{aligned} \tag{13}$$

Interestingly, under opacity, the optimal monetary policy coefficient (13) 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 the policy coefficient to be positive. The sign of the policy coefficient (13) depends on the relation between the degree of strategic complementarities $1 - \xi$, the preference of the central bank for output-gap stabilization λ, and the relative precision of firm's information σ_ρ^2/σ_u^2. In particular, the following condition holds:

$$\nu > 0 \Leftrightarrow \xi < \lambda \frac{\sigma_\rho^2}{\sigma_u^2} \qquad \text{and} \qquad \nu < 0 \Leftrightarrow \xi > \lambda \frac{\sigma_\rho^2}{\sigma_u^2}. \tag{14}$$

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

Degree of strategic complementarities The policy coefficient is positive when complementarities are high (ξ low). As opacity alleviates the effectiveness of monetary policy on the price level, strong complementarities reduce it even further. Two related intuitions can be mentioned for this effect to arise. First, 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 the 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 to output gap stabilization and the central bank finds it optimal to set a monetary policy coefficient that accommodates the aggregate demand: $\nu > 0$. Second, when the degree of strategic complementarities is high, the monetary instrument I has a small impact on the price level. This renders the price stabilization less effective and more difficult to achieve as aggregate demand variations have a smaller impact on the price level. The central bank then faces a trade-off that incites it to stabilize the output gap instead of the price level.
Figure 1 computes the central bank's response ν as a function of strategic complementarities $1 - \xi$ with $\sigma_u^2 = 1$, $\sigma_\rho^2 = 0.5$, and $\lambda = 1$ for three values of dispersion of central bank's signals σ_μ^2. As strategic complementarities increase, strategic uncertainty reduces the effectiveness of monetary policy and the policy coefficient ν increases. Not surprisingly, the strength of the central bank's response (absolute value of ν) increases with the precision of its signal.

Precision of private information When the relative precision of firms' private information increases (σ_ρ^2/σ_u^2 falls), the fundamental and strategic uncertainty of firms about the monetary instrument decreases. The reduction of uncertainty makes the monetary policy more effective to stabilize the price level and the trade-off favours the *lean against the wind* principle. This increases the

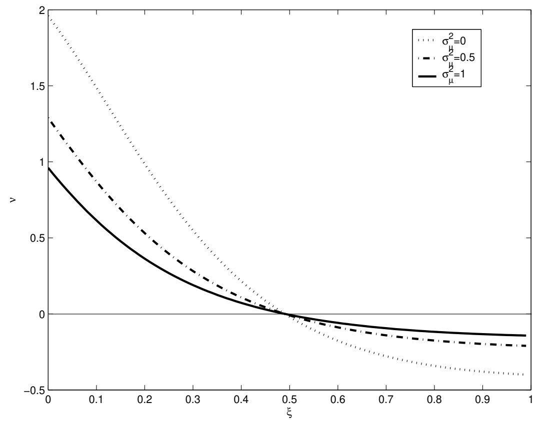

Figure 1: Optimal monetary policy under opacity (impact of σ_μ^2)

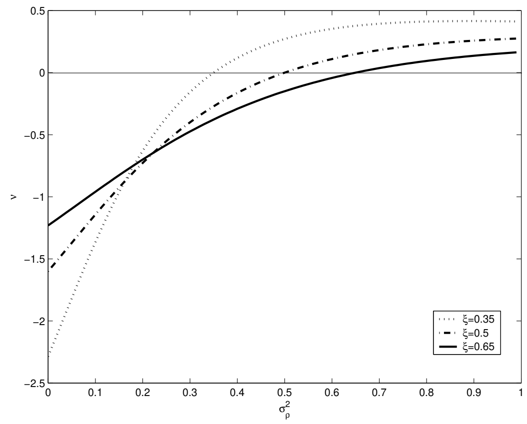

Figure 2: Optimal monetary policy under opacity (impact of σ_ρ^2)

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.

Figure 2 shows the optimal monetary policy as a function of the precision of firms' private information σ_ρ^2, with $\sigma_u^2 = 1$, $\sigma_\mu^2 = 0.25$, and $\lambda = 1$ for three values of complementarities ξ. When the precision of firms' private information increases (σ_ρ^2 falls), firms' uncertainty about cost-push shocks is reduced and prices respond more strongly to cost-push shocks. This increases the variability of the price level and the incentive of the central bank to stabilize the price level.

Central bank's preference Finally, when the central bank is more inclined towards 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 the *lean against the wind* principle is preferred to the *blow with the wind* principle.

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

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

The equilibrium pricing rule (10) is described by

$$p_i = \frac{\sigma_u^2\sigma_\mu^2}{\xi\sigma_u^2\sigma_\mu^2 + \sigma_u^2\sigma_\rho^2 + \sigma_\mu^2\sigma_\rho^2} u_i + \left[\frac{\sigma_u^2\sigma_\rho^2}{\xi(\xi\sigma_u^2\sigma_\mu^2 + \sigma_u^2\sigma_\rho^2 + \sigma_\mu^2\sigma_\rho^2)} + \nu\right] D. \qquad (15)$$

Minimizing the unconditional expected loss (11) subject to firms' pricing rule (15) 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 and satisfies the *lean against the wind* principle. Indeed, the 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 level of transparency ($0 < \sigma_\phi^2 < \infty$). More particularly, we examine the impact of an increase in transparency about central bank's monetary instrument on the optimal monetary policy. We show that small variations in transparency or in central bank's preferences can have large effects on the optimal conduct of

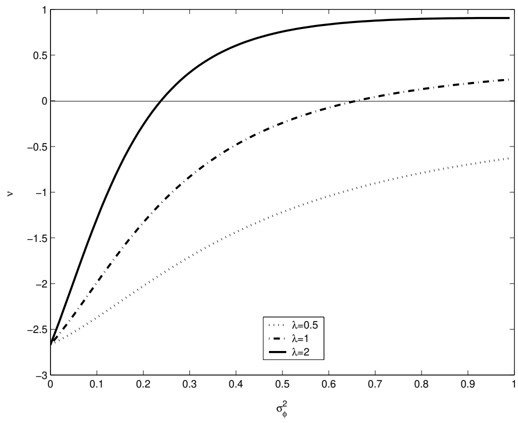

Figure 3: Optimal monetary policy (impact of λ)

monetary policy.

Figure 3 computes the central bank's response ν as a function of the degree of transparency σ^2_ϕ, with $\sigma^2_u = 1$, $\sigma^2_\mu = 0.5$, $\sigma^2_\rho = 0.5$, and $\xi = 0.25$ for three values of λ, the weight assigned to output gap variability.

First, for a given level of transparency (say $\sigma^2_\phi = 0.9$), a switch in preference towards greater price level stabilization from $\lambda = 1$ to $\lambda = 0.5$ renders the optimal monetary policy coefficient negative. When the central bank is less inclined towards output gap stabilization, it tends to contract nominal aggregate demand in a larger extent in order to reduce inflation.

Second, a small increase in transparency (σ^2_ϕ falls) may also have a large impact on the policy coefficient as it leads to a change in its sign. As more transparency reduces the cost of reducing inflation, the central bank finds it optimal to achieve a lower level of inflation by contracting nominal aggregate demand in a larger extent.

4.6 Discussion

Our result with respect to the optimal monetary policy in response to cost-push shocks under opacity gives an interesting insight into the conduct of monetary policy in the 70s. Over this decade, the world economy has experienced both important oil shocks and high inflation level. Yet, it seems that oil shocks alone could not account for the high level of inflation. As argued by Clarida et al. (2000) (p.168) for the case of the US economy, "*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 the conduct of monetary policy violated the so-called Taylor principle[8] in the pre-Volcker era and satisfied it during the Volcker-Greenspan era, they conclude that (p.178) "*one important question [their] paper raises but does not answer is the following: why is it that during the pre-1979 period the Federal Reserve followed a rule that was clearly inferior?*". The optimal monetary policy derived in our model provides a rationale for this puzzle.

De Long (1997) largely documents the evolution in the perception of the response to be adopted in case of cost shock occurrence. He underlines central bankers' concern for the impact of a restricive 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 is clearly unfavourable to inflation stabilization. Under opacity, the central bank can only reduce inflation at the cost of a strong decrease in output; as it becomes more transparent, the central bank can reduce inflation at a lower cost. De Long argues that the main reason for the inflation in the 70s lies in the "*shadow of the Great Depression*". The fear of recession (De Long (1997)) and the excessive emphasis on the output gap (Orphanides (2005)) are somehow rationalized in our model as the reduction of inflation leads to a much higher contraction in output under opacity than under transparency.

Hence, we can illustrate the development in the conduct of monetary policy in the US as follows. In the pre-Volcker era, the Fed was rather opaque with respect to nominal aggregate demand and did not assign as much weight to price stabilization as it does today. Our framework shows that opacity and some considerations for output gap may explain why central banks conducted an accommodating monetary policy in response to oil shocks.

Then, under Volcker, the Fed became much more inclined towards price stabilization.[9] This corresponds to a reduction in the value of λ and may imply according to (14) a switch from the *blow with wind* to the *lean against the wind* principle. In figure 3, a fall in λ leads to a down shift in the monetary policy coefficient.

Finally, under the influence of Greenspan, the Fed becomes much more transparent. Our analysis then suggests that the *lean against the wind* principle is always optimal when the degree of common knowledge about monetary instrument (nominal aggregate demand) is high among firms whatever the parameter configuration. As indicated on the figure, when the central bank is very transparent, the optimal monetary policy satisfies the *lean against the wind*

[8]The Taylor principle calls for an increase in nominal interest rate larger than the rise in expected inflation, so that the real interest rate rises as well. A central bank following this principle fights inflation as it contracts the economy whenever inflation expectations rise.

[9]See Orphanides (2005).

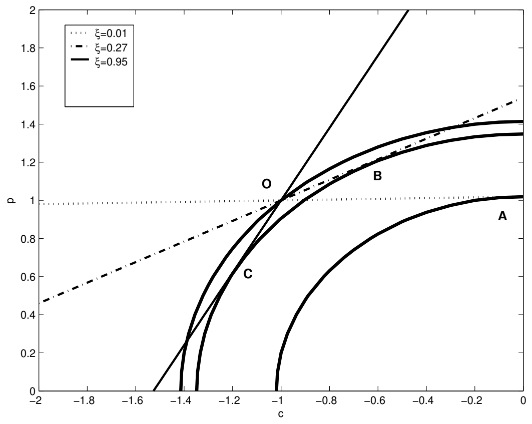

Figure 4: Phillips curves and economic outcomes under opacity: impact of strategic complementarities

principle even if the preference for output gap stabilization is large ($\lambda = 2$).

4.7 Phillips curves and economic outcomes

This section interprets former monetary policy issues in term of Phillips curves. 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.

The case of opacity derived in section 4.3 is represented by figure 4. It is computed with $\sigma_\mu^2 = \sigma_\rho^2 = \sigma_u^2/2$ and $\lambda = 1$ ($\sigma_\phi^2 \to \infty$ under opacity). 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 σ_ρ^2/σ_u^2. More particularly, when complementarities are extremely strong *or* precision of firms' information 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. Suppose that the economic outcome in the absence of central bank intervention is written O. When the central bank is opaque, the degree of complementarities relatively strong, and firms' information not too accurate, condition (14) says that the optimal monetary policy is expansive. The resulting economic outcomes are written A and B in figure 4. Reducing complementarities or increasing precision of firms' information reduces uncertainty (or its impact) and raises the slope of the Phillips curve under opacity as figure 4 shows. When firms' information is very accurate ($\sigma_\rho^2 \to 0$), the curve is vertical. From the slope of the Phillips curve depends whether the monetary policy is expansive (points A and B) or contractive (point C).

Figures 5 and 6 illustrate the economic outcome for different degrees of trans-

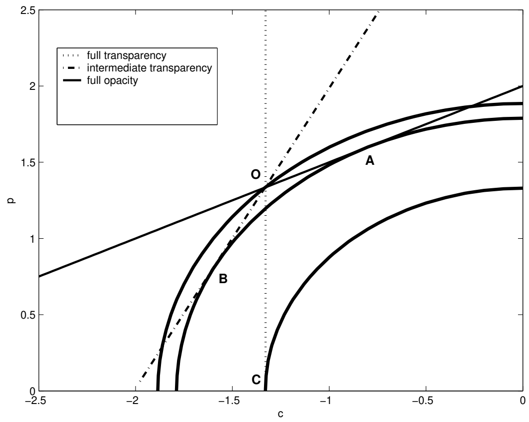

Figure 5: Phillips curves and economic outcomes: impact of transparency ($\lambda = 1$)

parency. The parameter values are $\sigma_\mu^2 = \sigma_\rho^2 = \sigma_u^2/2$, $\xi = 0.25$, and $\lambda = 1$ ($\lambda = 0.3$) for figure 5 (figure 6). 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 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 economic outcome indicated by point A. Interestingly, this analysis suggests that a central bank acting under opacity and choosing the economic outcome written A violates the *lean against the wind* policy: while inflation expectations rises because of a positive cost-push shock, the central bank expands nominal aggregate demand what exacerbates the rise in inflation. Econometricians examining such time series would conclude, as do Clarida et al. (2000) for the 1970s, that the central bank violates the Taylor principle. 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 6 illustrates the case where the central bank is more inclined towards price stabilization. The optimal monetary policy may be restrictive even for an opaque central bank. A shows the outcome resulting from a contractive monetary policy.

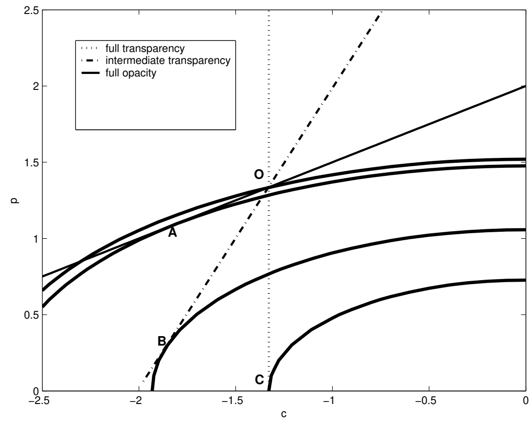

Figure 6: Phillips curves and economic outcomes: impact of transparency ($\lambda = 0.3$)

5 Concluding remarks

Excessive inflation 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 literature has called for transparency in order to achieve credibility.

Our model highlights the relevance of central bank's disclosure for the effectiveness of monetary policy in an economy characterized by strategic complementarities and imperfect common knowledge. We show that, even in the absence of inflationary bias, a credible central bank may find it optimal to accommodate monetary policy in response to cost-push shocks 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 violates the *lean against the wind* principle. As the central bank faces a trade-off between price and output gap stabilization, its disclosure influences the effectiveness of its policy, and thereby whether it will be involved into price or output gap stabilization. So, first, excessive inflation can be attributed to the lack of transparency and not necessarily to the lack of credibility. And second, our analysis underlines that transparency is not just a means to achieve central bank's credibility but plays a crucial role for the optimality of monetary policy implemented by a fully credible central bank.

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