Transparency and Monetary Policy Effectiveness

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Abstract

This article analyses the effects of economic transparency on the optimal monetary policy in an economy affected by demand shocks. In an environment of imperfect common knowledge, demand shocks create a trade-off between stabilising the price level and stabilising the output gap. The monetary policy implemented by the central bank tends, on the one hand, to offset demand shocks but, on the other hand, to distort the economy because of its mistaken view of the fundamental state of the economy. Transparency is optimal as long as the central bank does not weight the stabilisation of the output gap too heavily in its objective function.

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I Introduction

While central banks have for a long time had a reputation for secrecy, their recent increase in transparency is an important development in the conduct of monetary policy over the last decade [Blinder, 1998]. In general, the notion of transparency refers to the absence of informational asymmetry between the central bank and the private sector. Greater transparency is often justified by the willingness of an independent central bank to improve its credibility by making its action observable. The literature related to credibility issues mainly deals with the consequences of transparency for the reputation of central banks (particularly through the Barro-Gordon model). This literature reflects the recent institutional reforms that many central banks have undergone and the resulting controls on inflation.

However, in a time when central banks enjoy a high degree of credibility (especially in OECD countries), it is interesting to wonder whether the central bank should reveal all of its information to the private sector or whether it should keep privileged information. While the benefits of economic transparency are admitted by many practitioners, such as international financial institutions and central banks (see, e.g., International Monetary Fund [1999]), recent academic works have stressed the possible risks. For example, Morris and Shin [2002] highlight the problems that can be caused by the overreactions of economic agents to imprecise public announcements. There is therefore a debate about the stabilising effects of economic transparency[1]. The aim of this paper is to analyse how transparency on the part of credible central banks can improve the effectiveness of monetary policy.

We propose a model of monetary policy under imperfect common knowledge[2] in which the economy is affected by demand shocks. The central bank and firms are uncertain about the state of the economy. Our approach has two main features. First, we focus on the effects of transparency in a context where the central bank has no inflationary bias and where the private sector knows its preferences. Second, while the literature on imperfect

[1]Throughout this article, we will focus on the welfare effects of economic transparency as defined by Geraats [2002]. Economic transparency is related to the economic information used by central banks.

[2]Let us recall that a fact is common knowledge if everybody knows it, everybody knows that everyone knows it, and so on. It is necessary to abandon the assumption of common knowledge of the fundamental state of the economy (specifically the shocks affecting the economy) to understand the transmission mechanisms of information to markets.

common knowledge generally considers communication as the only task of the central bank and neglects the fact that communication is usually associated with an action, following Baeriswyl [2007], Baeriswyl and Cornand [2010a, 2010b], and Walsh [2006, 2007], we consider the monetary instrument of the central bank not only as a mechanism of action that stabilises the economy but also as a signal that indicates (partially) to firms its imperfect estimate of the fundamental state of the economy. In this context, monetary policy has a dual role, as an action and a vehicle for information. The central bank implements its policy by considering not only its action role but also the information that its instrument reveals to firms.

Depending on the degree of central bank transparency, firms are more or less able to interpret the views of the central bank on the economic situation. Transparency is characterised by the correct interpretation of the monetary instrument by firms.[3] In fact, the central bank provides more or less accurate information to firms on its own assessment of the shocks affecting the economy. The recent developments in terms of the dissemination by the U.S. Federal Reserve of information about its monetary policy provides a good illustration of the existence of various degrees of transparency. Until 1994, the Fed did not publicly announce the targeted interest rate. In this context, the private sector had to observe open market operations implemented by the trading desk of the Fed to decode the political decisions made by the Federal Open Market Committee (FOMC). This lack of transparency was a source of fundamental uncertainty about the targeted rate of the Fed and of strategic uncertainty about the beliefs of others about this target. Since February 1994, the Fed began to publish the new target set after each FOMC meeting. This publication reduces uncertainty about the numerical target and thus reduces the uncertainty in the interpretation of the policy decision. Since 1998, the FOMC decided to indicate after each meeting its estimate of possible changes of its future policy. Even more recently, the FOMC released the minutes of its deliberations.[4] This evolution in the practice of central banks clearly shows an increase in the degree of transparency.

In this paper, we analyse the optimal monetary policy and the effects of the central bank's transparency when its assessment of demand shocks is imperfect. The imperfection

[3] In this context, a transparent central bank discloses enough information that it reveals its own assessment of the fundamental shocks to the firms using its monetary instrument. On the other hand, an opaque central bank does not share its information with the firms.

[4] See Poole [2005] for a description of this evolution.

of the central bank's information generates a trade-off between stabilising the output gap and stabilising the price level. The assessment error of the central bank creates more or less distortion in the output gap and the price level depending on the reaction of firms to their private signal and to the monetary instrument. The propensity of the central bank to respond to its assessment of the demand shock captures the trade-off between neutralising the demand shock and distorting the economy. By making the monetary instrument common knowledge among firms, transparency favours the inclusion of the instrument in their pricing decision. Transparency is beneficial in stabilising the price level when firms do not respond too strongly to the central bank's error, that is, when fundamental and strategic uncertainty is high. A weak reaction of firms to the monetary instrument is detrimental to the stabilisation of the output gap. In the realistic case where firms have less accurate private information than the central bank, transparency is beneficial as long as the output gap deviations are not weighted too heavily in the social welfare function. Our framework gives a new rationale for the recent evolution of central banks towards more transparency.

This article is structured as follows. Section II situates our approach within the literature and identifies its original features. Section III briefly describes the economy in which firms' pricing decisions are strategic complements. Section IV presents the basic case under perfect common knowledge, thus recalling monetary policy standard results and providing useful benchmarks to understand our main results. Section V discusses the optimal monetary policy and the optimal degree of transparency when the economy is affected by demand shocks of which the central bank and firms have imperfect common knowledge. This section shows that transparency is optimal in such a context for the more realistic parameter settings. Finally, Section VI concludes the article.

II The Transparency Debate

The way that the central bank communicates its views and decisions to the private sector is currently under debate. Most of the literature examines the welfare effects of transparency in terms of the central bank's credibility in the framework of Barro and Gordon [1983].[5]

[5] As central banks are supposed to be willing to boost the economy above its natural level, the literature examines how transparency can reduce the inflationary bias and time inconsistency problem and can increase the credibility of central banks. See Geraats [2002] for a review of the literature.

In the current context of central bank independence and historically – and durably – low levels of inflation, many central banks have reached a high degree of credibility, at least in OECD countries. For this reason, in this section, we ignore the inflation bias problem and focus on the welfare effects of transparency for credible and well-established central banks, which is the basic assumption of the model proposed in this paper. We propose to analyse the extent to which public information dissemination (the revelation to the private sector by the central bank of its own estimate of the fundamental state of the economy) may generate distortion effects in the use of information and therefore may be detrimental to welfare. Then, we focus on the link between transparency and monetary policy effectiveness.

II.1 Distortion in the Use of Information

A first set of arguments focuses on the idea that transparency may exacerbate the reaction of the market and distort the economic outcome compared to what would be justified by the fundamentals alone.

In their canonical beauty contest game, Morris and Shin (2002) show that in an environment of imperfect common knowledge characterised by the presence of strategic complementarities, increasing the precision of a public announcement may be detrimental to the welfare because market participants ascribe to it a greater weight than would be justified by its face value. The overreaction to public information can be harmful when it is noisy because it destabilises the economy. For this reason, it may be preferable, under certain circumstances, to withhold information rather than to disclose information publicly.

However, if Morris and Shin consider that their argument goes against transparency, Svensson [2006] argues that it is clearly in favour of transparency. In the model of Morris and Shin, for transparency to be detrimental to welfare, the central bank's information has to be less accurate than private information. In reality, however, the information available to public institutions is generally more accurate than information available privately [Romer and Romer, 2000]. Morris, Shin and Tong [2006] respond to this criticism by incorporating correlated signals in their analysis and by showing that the result holds

even if the public signal is more accurate than the private signals.[6]

While the debate between Morris and Shin and Svensson focuses on two extreme cases of information disclosure (full transparency vs. full opacity), Cornand and Heinemann [2008] show that limited information publicity improves welfare by reducing the degree of common knowledge and thus limiting the overreaction of agents to public information. This result supports the conclusion of Morris and Shin since maximum transparency is not optimal even if the central bank has more precise information than the private sector.

Hellwig [2005] analyses the welfare effects of public information dissemination in a model of monopolistic competition among firms receiving heterogeneous information. He shows that information heterogeneity leads to more or less important delays in price adjustments and magnifies the real effects of monetary shocks. Public announcements reduce adjustment delays but increase the volatility associated with information errors. Such announcements always improve welfare because they reduce price dispersion among firms. The difference in results between Morris and Shin and Hellwig can be explained by the difference in the definition of social welfare considered in the two studies, especially the weight given to coordination in the social welfare (see, e.g. Angeletos and Pavan [2007a, b]).

This analytical framework has been criticised, especially because the endogenous nature of information is not taken into account and because there is no adequate pricing theory [Atkeson, 2001]. Morris and Shin [2005] have responded to this criticism by explicitly incorporating the issue of information endogeneity. When it discloses information, the central bank exerts an influence on market expectations. At the same time, it collects information from markets to assess the economic situation and make decisions. There is a tension between these two roles of monetary policy [Amato and Shin, 2006]: if the central bank exerts a strong influence on agents' expectations, then it does not observe in the economy the expectations of private agents but rather their expectations revised through the information disclosed by the central bank itself. Therefore, Baeriswyl [2011] shows that, accounting for the endogeneity of the central bank's information, the accuracy of private agents' information does not increase monotonically in the degree of transparency

[6] With correlated signals, the public signal provides an additional indication about private agents' errors and will be better incorporated in their efforts to guess the behaviour of others, even for lower levels of precision of the public signal.

and that the optimal degree of transparency is always lower than in an economy where the central bank's information is independent of its communication strategy.

II.2 Monetary Policy Effectiveness

Simultaneously with the increase in central banks' transparency, monetary policy has itself become more efficient. The link between transparency and monetary policy effectiveness has been studied in various ways. Some papers emphasise the role of transparency on stabilisation and inflation surprise[7], while others stress the role of monetary policy in determining demand, in particular through an arbitrage between short-term and long-term rates[8]. Some others consider the effectiveness of monetary policy in maintaining price stability; here, we focus on this literature (our model is directly inspired by this strand of the literature). Baeriswyl and Cornand [2010a] show that the optimal response of the central bank to cost-push shocks is a function of its communication strategy. Because cost-push shocks create a trade-off between inflation and output gap stabilisation, the central bank chooses whether it should adopt an accommodating monetary policy in response to nominal aggregate demand shocks to reduce the negative output gap (at the expense of higher inflation) or whether it should contract nominal aggregate demand to fight inflation (at the expense of a higher output gap), depending on the effectiveness of its policy to influence inflation and the output gap. When the central bank is opaque, firms' fundamental and strategic uncertainty about the monetary instrument is high, which reduces the effectiveness of monetary policy to stabilise inflation. Therefore, it is optimal for the central bank to adopt a policy of expansive nominal aggregate demand in response to positive cost-push shocks. However, as shown by Baeriswyl and Cornand [2010b], transparency about cost-push shocks is detrimental to welfare. Because cost-push shocks create a trade-off between inflation and output gap stabilisation, they necessarily generate losses. The magnitude of the resulting loss depends on the strength of the firms' reaction.

[7] Cukierman [2001] and Gersbach [2003] analyse the effect of asymmetric information on the shocks affecting the economy. They assume that the central bank directly controls inflation and influences the output gap only insofar as inflation comes as a surprise. If the central bank reveals to the private sector its own assessment of economic conditions, the latter anticipates the response of the central bank to inflation and stabilisation is no longer possible.

[8] Blinder [1998] and Woodford [2005] emphasise that the central bank can influence the long-term interest rate and asset prices only to the extent that it can influence the market's expectations about the future short-term interest rate. Central bank transparency facilitates the prediction of targeted future rates and therefore increases the effectiveness of monetary policy on the demand side.

When pricing decisions are characterised by strategic complementarities, firms set their price not only as a function of their own expectations of the cost-push shock but also according to their expectations of the expectations of others about this shock. By reducing uncertainty, transparency increases firms' response to these shocks, which is harmful in terms of welfare. Transparency can thus have an ambiguous effect on welfare in a situation where cost-push shocks are predominant.

Finally, our model fits well within two streams in the literature: that of coordination games la Morris and Shin, where the central bank's communication can have a distorting effect, and that of traditional monetary policy, where the central bank implements an action to stabilise an economy plagued by demand shocks. This analytical framework allows us to derive the optimal monetary policy based on the communication strategy of the central bank and to address the impact of transparency on the effectiveness of monetary policy.

III The Economy

The model is derived from an economy consisting of a representative household, a continuum of monopolistically competitive firms, and a central bank. The economy is affected by stochastic demand shocks. Monetary nonneutrality comes from the assumption of informational friction that is imperfect common knowledge[9].

III.1 Firms

The main equation of our model is the optimal pricing rule of each firm i:

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

where $\mathbb{E}_i$ is the expectation operator of firm i conditional on its information set. The pricing rule (1) states that firm i chooses its price according to its expectation of the

[9]The incentive for this type of modelling (compared to the standard literature, where the real effects of monetary policy are generated by the rigidity of prices) has been recently highlighted by Mankiw and Reis [2002], Hellwig [2002], Woodford [2003] and Adam [2007]. They show that when there is a lack of common knowledge on the fundamentals of the economy, monetary policy can have real and persistent effects whose dynamic properties are more realistic than those of sticky-price models. In particular, they show that higher order uncertainty generates inertia not only on the price level but also on inflation, which models with sticky prices fail to capture without the inclusion of ad hoc hypotheses.

overall price level p and the real output gap c.[10] Using the fact that the nominal aggregate demand y can be expressed as $y = c + p$, we can rewrite the pricing rule (1) as follows:

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

Thus, each firm sets its prices according to its expectation of the price level and the nominal aggregate demand. The expression $(1-\xi)$ defines the degree of strategic complementarities between prices because the price level is the average of the prices set by firms $p = \int_i p_i di$. Throughout this paper, we assume that prices are strategic complements, i.e., $0 \leq \xi \leq 1$, which appears to be the most realistic case.

III.2 The Central Bank

The central bank seeks to minimise both the variability of the output gap c and that of the price level p by adjusting its monetary instrument I:

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

where $\mathbb{E}_{cb}$ is the expectation operator of the central bank conditional on its information set and λ the weight assigned to output gap variability. We assume that the instrument of the central bank directly influences the nominal aggregate demand.

III.3 Nominal Aggregate Demand

The nominal aggregate demand y is determined, on the one hand, by a demand shock g and, on the other hand, by the monetary policy instrument implemented by the central bank I: $y = g + I$. For the sake of simplicity, we assume that the demand shocks that affect the economy are normally and independently distributed:

$$g \sim N(0, \sigma_g^2).$$

As the monetary instrument I partly determines the nominal aggregate demand, the

[10] For further details on the microfoundations of a simple model of monopolistic competition under imperfect information, see Adam [2007].

pricing rule can be written as

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

IV Monetary Policy under Common Knowledge

Standard monetary policy assumes that information is common knowledge among firms. While this paper focuses on monetary policy under imperfect common knowledge, this section presents, as a benchmark case, the optimal monetary policy under (perfect) common knowledge.

When information is perfect and common to all firms, each firm sets the same price. The pricing rule (4) can therefore be simplified as follows:

$$p_i = p = I + g.$$

When the central bank also benefits from perfect information, its instrument can simply be written as

$$I = \nu g,$$

where ν is the monetary policy coefficient. The resulting loss under perfect information is given by

$$L = [(1+\nu)g]^2,$$

and minimising the unconditional expected loss, we get the following optimal monetary policy:

$$\nu \;=\; -1.$$

This result is in line with standard optimal monetary policy analysis.[11]. The coefficient indicates that the central bank adjusts its instrument to perfectly compensate for the de-

[11] See Clarida, Gali and Gertler [1999] for a literature review on monetary policy in a new Keynesian framework.

mand shock. By filling in the output gap, the central bank also eliminates price variations. Thus, demand shocks are perfectly neutralised.

V Monetary Policy under Imperfect Common Knowledge

Let us now focus on the more realistic situation where the state of the economy is imperfect common knowledge among firms; the latter indeed get differentiated information on the demand shock g and the monetary instrument I depending on the degree of transparency of the central bank. Note, however, that the structure of the economy is common knowledge. We derive the optimal monetary policy as a function of the central bank's transparency and then analyse the welfare effects of transparency.

As the information disclosed via the monetary instrument influences the reaction of firms, the optimal policy varies as a function of the communication strategy adopted by the central bank. The central bank plays the role of a Stackelberg leader in so far as it determines its instrument by anticipating the reaction of firms to its own instrument.

We present two extreme information structures in the economy. In the opacity case, firms cannot observe the instrument and use their private information about the demand shocks to guess the policy implemented by the central bank. By contrast, under transparency, the monetary instrument is common knowledge among firms.

The central bank receives a private signal on the demand shock that deviates from the true fundamental state with an error term that is normally distributed:

$$g_{cb} = g + \eta, \quad \text{with} \quad \eta \sim N(0, \sigma_\eta^2).$$

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

$$I = \nu(g + \eta). \tag{5}$$

V.1 Opacity

Each firm i receives a private signal g_i on the demand shock g that can be interpreted as a private estimate. The private signal of each firm deviates from the true demand shock

with an error term that is normally distributed:

$$g_i = g + \varepsilon_i, \quad \text{with} \quad \varepsilon_i \sim N(0, \sigma_\varepsilon^2),$$

where the ε_i are identically and independently distributed among firms.

Under opacity, firms do not observe the monetary instrument. They are nevertheless aware that the central bank neutralises demand shocks according to its information. Firms use their private information g_i rationally to infer the monetary instrument I.

V.1.1 Equilibrium

To determine the perfect Bayesian equilibrium behaviour of firms, let us recall the optimal pricing rule (4) and successively substitute the average price level by higher order beliefs on demand shocks and the monetary instrument

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

Note that the average expectation operator $\bar{\mathbb{E}}(.)$ is such that $\bar{\mathbb{E}}(.) = \int_i \mathbb{E}_i(.)di$. Under heterogeneous information, the law of iterated expectations fails, and the higher order expectations cannot be simplified by the average expectation of degree one[12]. Hence, we can write the pricing rule as follows:

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

and averaging over all firms,

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

where k is the degree of higher order iterations. We use the following notation: $\bar{\mathbb{E}}^{(0)}(x) = x, \bar{\mathbb{E}}^{(1)}(x) = \bar{\mathbb{E}}(x)$, and $\bar{\mathbb{E}}^{(2)}(x) = \bar{\mathbb{E}}\bar{\mathbb{E}}^{(1)}(x) = \bar{\mathbb{E}}\bar{\mathbb{E}}(x)$. The price level p is a weighted average of the higher order beliefs about the nominal aggregate demand. The corresponding output

[12] See Morris and Shin [2002].

gap is given by

$$c = y - p = g + I - \sum_{k=0}^{\infty}(1-\xi)^k\Big[\bar{\mathbb{E}}^{(k+1)}(\xi g + \xi I)\Big]. \tag{7}$$

The output gap is the difference between the nominal aggregate demand and the weighted average of the higher order beliefs about it. As the fundamental and strategic uncertainty about the nominal aggregate demand increases, the real effect of variations in demand also increases. In the particular case where it is common knowledge, the nominal aggregate demand only has a price effect.

To solve the inference problem of each firm[13]

$$\mathbb{E}_i(g, I) = \mathbb{E}\left(\begin{array}{c|c} g & \\ I & g_i \end{array}\right) = \left(\begin{array}{c} \Omega_1 \\ \Omega_2 \end{array}\right) g_i,$$

we use the fact that the monetary policy coefficient is common knowledge among firms, so that

$$\begin{aligned} \Omega_1 &= \frac{\sigma_g^2}{\sigma_g^2 + \sigma_\varepsilon^2} \\ \Omega_2 &= \frac{\nu\sigma_g^2}{\sigma_g^2 + \sigma_\varepsilon^2} = \nu\Omega_1. \end{aligned}$$

By integrating this result in equation (6), we get

$$\begin{aligned} p &= \xi\sum_{k=0}^{\infty}(1-\xi)^k\Big[\Omega_1^{k+1}(1+\nu)g\Big] \\ &= \frac{\xi\Omega_1(1+\nu)}{1-(1-\xi)\Omega_1}g = \gamma g. \end{aligned} \tag{8}$$

V.1.2 Optimal Monetary Policy

The optimal monetary policy consists of choosing the instrument (5) that minimises the unconditional expected loss (3) subject to the pricing rule (8). The variance of the price level is simply given by

$$\mathrm{var}(p) = \gamma^2\sigma_g^2,$$

[13]Note that the conditional expectation can be reduced to a linear projection because the model is linear-Gaussian.

while the variance of the output gap is given by

$$\text{var}(c) = (1 + \nu - \gamma)^2 \sigma_g^2 + \nu^2 \sigma_\eta^2.$$

From (3), the central bank minimises the loss

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

The perfect Bayesian equilibrium is found by simultaneously solving the pricing rule (8) and the optimal monetary policy problem described above. The resolution gives us the following pricing rule and optimal monetary policy

$$\begin{aligned} p_i &= \gamma g_i = \frac{\lambda \xi \sigma_g^2 \sigma_\eta^2 (\xi \sigma_g^2 + \sigma_\varepsilon^2)}{\sigma_g^2(\xi^2 \sigma_g^4 + \lambda \sigma_\varepsilon^4) + \lambda \sigma_\eta^2 (\xi \sigma_g^2 + \sigma_\varepsilon^2)^2} g_i \quad \text{and} \\ \nu &= -\frac{\sigma_g^2}{\sigma_g^2 + \sigma_\eta^2 \underbrace{\frac{\lambda(\xi^2 \sigma_g^4 + 2\xi \sigma_g^2 \sigma_\varepsilon^2 + \sigma_\varepsilon^4)}{(\xi^2 \sigma_g^4 + \lambda \sigma_\varepsilon^4)}}_{\omega}}. \end{aligned} \tag{9}$$

Equation (9) describes the value of the coefficient of central bank's optimal reaction to the demand shock. Note that the magnitude of central bank's response is a function of the precision of its information σ_η^2, of the weight attributed to output gap stabilisation λ, of the degree of strategic complementarities $1 - \xi$, and of the precision of firms' private information σ_ε^2.

First, note that the strength of the central bank's response increases with the precision of its private information ($\partial|\nu|/\partial\sigma_\eta^2 < 0$). When the demand shock is perfectly known by the central bank ($\sigma_\eta^2 = 0$), monetary policy perfectly neutralises demand shocks ($\nu = -1$). In the case where the central bank does not have relevant information on the shock ($\sigma_\eta^2 \to \infty$), its response to the shock is zero ($\nu = 0$).

The other parameters have an impact on the monetary policy coefficient through the ratio ω, which affects how the variance of central bank's signal errors σ_η^2 is taken into account in its reaction to the shock. The way this error is taken into account depends on the destabilising effect of its instrument on the economy according to the fundamental and strategic uncertainty of firms. There is thus a trade-off for the central bank between

neutralising the demand shocks and distorting the economy. Price level stabilisation is maximal when firms expect no output gap. The output gap can be filled either by the central bank's instrument or by the reaction of firms (through the price level) to the demand shock. The cost of stabilising the output gap owing to the monetary instrument comes from the distortion of the economy associated with the error in the central bank's information. The cost of stabilising the output gap owing to the reaction of the price level comes from the low price level stabilisation itself. The central bank therefore chooses its monetary policy to minimise its welfare loss by optimising the intensity of the output gap stabilisation owing to its instrument (at the expense of a distortion) and owing to the price level (at the expense of a variation in the price level).

More precisely, three effects can be identified when the central bank weakens its response to the demand shock ($\omega > 1$). First, the central bank reduces the price level stabilisation because firms respond more strongly to their private signal, anticipating a low monetary instrument (negative effect of price destabilisation). Second, the strong reaction of the price level favours output gap stabilisation (positive effect of output gap stabilisation). Third, a weaker response of the central bank reduces the output gap destabilisation associated with its error σ_η^2 (positive effect of not distorting the output gap).

Consider now the response of the central bank depending on the parameters of the model.

First, note that the reaction of the central bank decreases as the central bank's preference for output gap stabilisation increases, i.e., $(\partial|\nu|/\partial\lambda < 0)$. In the particular case where the output gap has no weight in the objective function ($\lambda = 0$), the central bank ignores the destabilising effect of its instrument on the output gap and responds to the shock without taking its error into account, i.e., $\nu = -1$. Conversely, the more the central bank is willing to stabilise the output gap, the more its response decreases with its error ($\nu = 0$ when $\lambda \to \infty$). In the case where the central bank ignores the variation of the price level, it does not respond to the demand shock. Anticipating the inaction of the central bank to stabilise nominal demand, firms fully react to the demand shock by adjusting their price, which perfectly stabilises the output gap.

Second, the central bank's response is a function of the degree of strategic complementarities. FIGURE 1 represents the policy coefficient ν as a function of the level of strategic

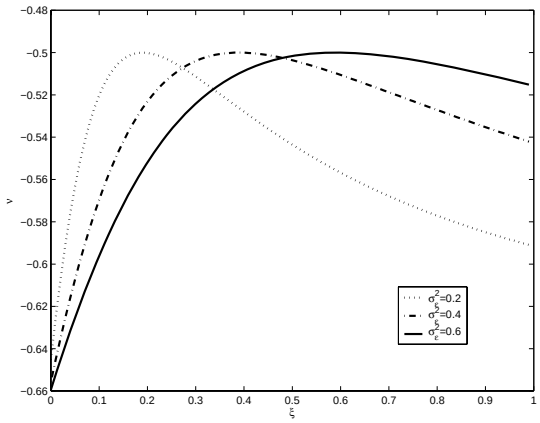

FIGURE 1 - Optimal Monetary Policy under Opacity

complementarities $1-\xi$ with $\sigma_g^2 = 1$, $\sigma_\eta^2 = 0.5$, and $\lambda = 1$, and for three values of the dispersion of private signals σ_ε^2. When the degree of strategic complementarities is maximal ($\xi = 0$), the quotient ω is equal to 1, and the optimal policy becomes $\nu = -\sigma_g^2/(\sigma_g^2 + \sigma_\eta^2)$. When $\xi = 0$, only the coordination motive (the average price level) intervenes in the pricing rule of firms. Consequently, firms do not respond to their private signal ($\gamma = 0$), which implies $p = 0$. As firms do not respond to the shock, the central bank cannot influence the price level determination owing to its instrument. In this case, the central bank stabilises the output gap $c = g + I - p$ by simply weighting its reaction to the demand shock by the precision of its information.

As ξ increases ($0 < \xi < \lambda\sigma_\varepsilon^2/\sigma_g^2$), fundamentals have an increasing impact on pricing decisions and firms take their private signal more into account. As firms take the monetary instrument into account in their behaviour, the central bank can thereby influence the price level by changing its reaction to the shock ($\omega \neq 1$) in order to reduce the distortion of its policy on the output gap. A weaker response of the central bank to the demand shock increases the reaction of firms and that of the price level. A stronger reaction of the price level to the demand shock, on the one hand, generates a loss in terms of price stability but, on the other hand, better stabilises the output gap (and without any distortion associated with the central bank's error σ_η^2).

The minimal level of the central bank's response is reached when $\xi = \lambda\sigma_\varepsilon^2/\sigma_g^2$; the value of the monetary policy coefficient is thus given by $\nu = -\sigma_g^2/[\sigma_g^2 + \sigma_\eta^2((1+\lambda\sigma_g^2)^2)/(1+\lambda\sigma_g^4)]$.

For higher values of ξ ($\xi > \lambda\sigma_\varepsilon^2/\sigma_g^2$), the reaction of the price level becomes stronger (because the strategic complementarities are lower) and the central bank intensifies its

response to the demand shock so as not to exacerbate price level destabilisation ($\partial|\nu|/\partial\xi > 0$ when $\xi > \lambda\sigma_\varepsilon^2/\sigma_g^2$).

V.2 Transparency

Under transparency, in addition to their private signal on the demand shock, firms observe the monetary instrument. The private signals on demand shocks have the same properties as those described in the opacity case. Each firm i also receives a signal on the monetary instrument that can be written, in its general form, as follows:

$$I_i = I + \phi_i, \quad \text{with} \quad \phi_i \sim N(0, \sigma_\phi^2). \tag{10}$$

When the central bank is fully transparent, each firm observes the true monetary instrument implemented by the central bank I ($\sigma_\phi^2 = 0$), and the instrument is a public signal that is common knowledge among firms. Note that the opacity case presented in the former section can be expressed here as the case with infinitely noisy private signals on the instrument ($\sigma_\phi^2 \to \infty$). One can imagine any intermediate situation where the monetary instrument is neither common knowledge nor unobservable, as we will see later. The parameter σ_ϕ^2 captures the degree of the central bank's transparency about its instrument.

V.2.1 Equilibrium

To determine the equilibrium pricing rule, we proceed as before. To solve the inference problem of each firm i

$$\mathbb{E}_i(g, I) = \mathbb{E}[g, I | g_i, I_i], \tag{11}$$

we define the corresponding variance-covariance matrix $\mathbf{V}_{4\times4}$ and the associated submatrices

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

The expectation of the demand shock and the instrument conditional to the information set of firm i is given by

$$\mathbb{E}\left(\begin{array}{c|c} g & \\ I & g_i, I_i \end{array}\right) = \mathbf{\Omega}\begin{pmatrix} g_i \\ I_i \end{pmatrix} = \begin{pmatrix} \Omega_{11} & \Omega_{12} \\ \Omega_{21} & \Omega_{22} \end{pmatrix}\begin{pmatrix} g_i \\ I_i \end{pmatrix},$$

where $\mathbf{\Omega} = \mathbf{V_{uo}}\mathbf{V_{oo}^{-1}}$. We can express the price equation (6) by

$$p = \sum_{k=0}^{\infty}(1-\xi)^k\Big[\begin{pmatrix} \xi & \xi \end{pmatrix}\mathbf{\Omega^{k+1}}\begin{pmatrix} g \\ I \end{pmatrix}\Big],$$

and the perfect Bayesian equilibrium strategy of firm i is a linear combination of its signals g_i and I_i:

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

V.2.2 Optimal Monetary Policy

Under transparency, the variance of the price level is given by

$$\text{var}(p) = (\gamma_1 + \gamma_2\nu)^2\sigma_g^2 + (\gamma_2\nu)^2\sigma_\eta^2,$$

and the variance of the output gap is given by

$$\text{var}(c) = (1 + \nu(1-\gamma_2) - \gamma_1)^2\sigma_g^2 + (\nu(1-\gamma_2))^2\sigma_\eta^2.$$

In the particular case of full transparency ($\sigma_\phi^2 = 0$), the optimal monetary policy satisfies $\nu = -\sigma_g^2/(\sigma_g^2 + \sigma_\eta^2)$. When the monetary instrument is common knowledge among firms, the central bank tries to neutralise demand shocks given the precision of its information.

Note here that the magnitude of the optimal response of the central bank under opacity

(9) is smaller than under transparency when $\sigma_\varepsilon^2/\sigma_g^2 > \xi(1-\lambda)/(2\lambda)$. As we have already observed, the central bank weakens its response to the demand shock when the negative effect associated with price destabilisation is dominated by the positive effect associated with output gap stabilisation (via the price level) and the positive effect associated with the absence of distortion in the output gap (via central bank's error). Concretely, the negative effect associated with price destabilisation is dominated by the positive effects either when the weight λ attributed to output gap stabilisation is large or when the price level reacts only weakly to shocks, that is, when fundamental uncertainty (σ_ε^2) and strategic complementarities ($1-\xi$) are high.

V.3 Welfare Effects of Transparency

Let us now analyse the optimal communication policy of the central bank. We particularly examine whether the central bank should be transparent (or not) about its monetary instrument. To this end, we proceed in two stages. First, we compare the two extreme cases of communication policy, i.e., opacity vs. transparency. Then, we consider an intermediate degree of transparency.

V.3.1 Transparency vs. Opacity

Between transparency and opacity, what is the best communication strategy for the central bank? Transparency has a differentiated effect on the output gap and price level stabilisation depending on the degree of uncertainty of firms. Because under transparency the monetary instrument is common knowledge among firms, the price level adjusts to the central bank's evaluation mistake η. A response of firms to this error is beneficial to output gap stabilisation because the neutralisation error of nominal demand can be compensated by an appropriate reaction of the price level. By contrast, firms' response to the error of the central bank is detrimental to price level stabilisation.

On the one hand, the output gap stabilisation is effective when firms respond strongly to their private signal. We can show that transparency favours output gap stabilisation when $\xi > \lambda\sigma_\varepsilon^2/\sigma_g^2$, that is, when the fundamental uncertainty (σ_ε^2) and the degree of strategic complementarities ($1-\xi$) are low. A low level of uncertainty reinforces firms' response to the private signal, which stabilises the output gap and which reduces the

propensity of the central bank to distort the output gap with its instrument. Transparency thus has a positive effect on output gap stabilisation when firms' response to their private signal under transparency (γ_1 given by equation (12)) is stronger than under opacity (γ given by equation (8)). Indeed, $\gamma_1 > \gamma$ when $\xi > \lambda\sigma_\varepsilon^2/\sigma_g^2$.

On the other hand, transparency is detrimental to price level stabilisation when firms respond strongly to the error of the central bank, that is, when fundamental uncertainty of firms and strategic complementarities are low.

The effect of transparency on welfare (3) therefore depends mainly on the relative weights attributed to output gap and price level stabilisation.

FIGURE 2 and FIGURE 3 illustrate the unconditional expected loss under transparency L_T relative to the unconditional expected loss under opacity L_O. Values above 1 indicate that the expected loss is higher under transparency rather than under opacity (i.e., transparency is detrimental to welfare).

FIGURE 2 represents the relative loss as a function of the central bank's error σ_η^2 for three values of private signal errors σ_ε^2, taking the following parameter values: $\xi = 0.25$, $\sigma_g^2 = 1$, and $\lambda = 1$. When the central bank weights deviations of the price level and deviations of the output gap equally, transparency is always beneficial even when the central bank has less precise information than firms.

FIGURE 3 illustrates the relative loss as a function of λ for three levels of private signal precision ($\xi = 0.25$, $\sigma_g^2 = 1$, and $\sigma_\eta^2 = 0.5$). Transparency can be detrimental for extreme values of λ. More precisely, transparency is welfare detrimental when the central bank strongly weights deviations of the price level (λ small) and firms' private information is relatively precise. In this case, opacity weakens firms' reaction by increasing uncertainty, which favours price level stabilisation. Transparency is also detrimental when the central bank strongly weights output gap deviations and firms' private information is relatively imprecise.

Note, however, that cases in which firms' private information is more precise than the central bank's information are very unlikely. Indeed, in an empirical analysis on American data, ROMER and ROMER [2000] show that the information of the Federal Reserve is more precise than that of commercial banks. Such a feature is not surprising because central banks spend large resources to collect information and also benefit from privileged sources

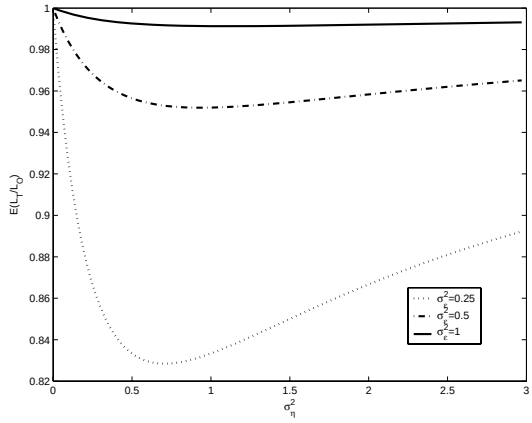

FIGURE 2 - Welfare Effects of Transparency for $\lambda = 1$

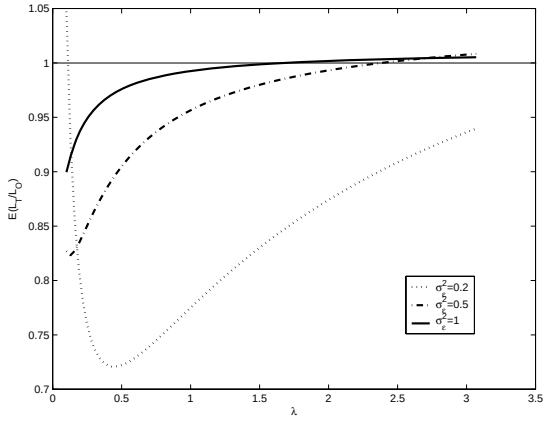

FIGURE 3 - Welfare Effects of Transparency for $\sigma_\eta^2 = 0.5$

such as data related to banking supervision.[14] Thus, we can conclude that for realistic parameter configurations (when the central bank's information is at least as precise as that of firms, $\sigma_\eta^2 < \sigma_\varepsilon^2$), transparency is beneficial in an economy affected by demand shocks, except if the central bank assigns a much larger weight to output gap stabilisation than to price level stabilisation.

V.3.2 Optimal Degree of Transparency

We now consider the case where the central bank can be partly transparent about its instrument. This accounts for the fact that the central bank discloses information that can contain some uncertainty, so that it is not common knowledge among the private sector. Indeed, central banks are well known for speaking with some degree of ambiguity (central banks' announcements are often called "mystic"). For example, Greenspan described his

[14] PEEK ET AL. (1999) show that the use of data related to banking supervision increases the precision of macroeconomic forecasts in the United-States.

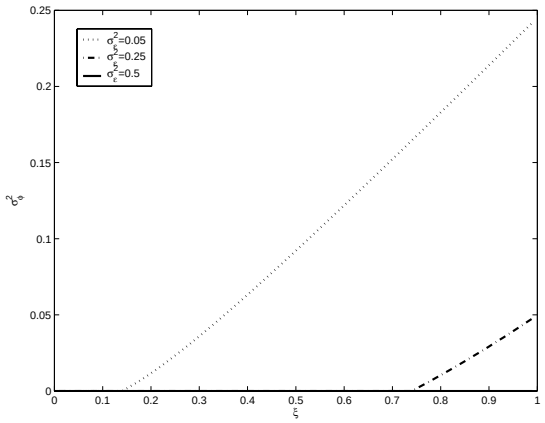

FIGURE 4 - Optimal Degree of Transparency for $\lambda = 1$

communication strategy in front of the American Congress in 1987 in these terms: "*Since I have become a central banker, I have learned to mumble with great incoherence. If I seem unduly clear to you, you must have misunderstood what I said.*" This quotation clearly illustrates the fact that central bankers sometimes intentionally express themselves in an ambiguous manner. The information disclosed by the central bank should therefore be interpreted with caution, and the strategic uncertainty associated with the interpretation of this information by others avoids common knowledge.

While the previous section shows that transparency is better than opacity for the most plausible parameter combinations, here we consider the optimality of partial transparency. The optimal degree of transparency determines the extent to which the central bank should be ambiguous about its monetary instrument. The degree of transparency is represented by the error σ_ϕ^2 in equation (10).

FIGURE 4 represents the optimal degree of transparency with $\sigma_g^2 = 1$, $\sigma_\eta^2 = 0.5$, and $\lambda = 1$. Full transparency (i.e., $\sigma_\phi^2 = 0$) is optimal whenever firms' information is not more precise than the central bank's information. The figure shows that partial transparency is optimal when firms' information is very precise. Indeed, if the error of the central bank is larger than firms' individual errors, transparency may distort the price level towards the error of the central bank; in this context, it is better for the central bank to be partly opaque. As underlined above, such parameter values are however not realistic. Hence, full transparency improves welfare for plausible parameter combinations. Indeed, transparency allows the central bank to orient firms' actions towards its instrument, which reduces output gap distortion.

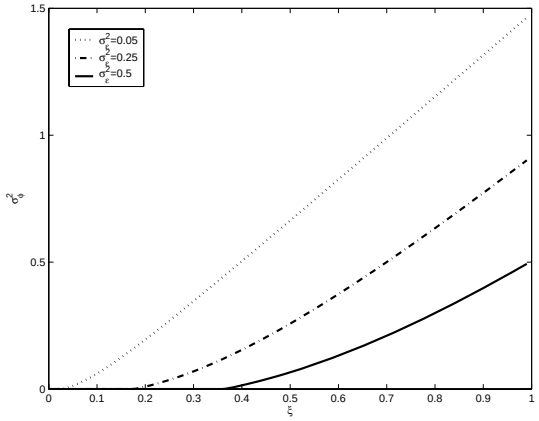

FIGURE 5 - Optimal Degree of Transparency for $\lambda = 0.25$

FIGURE 5 represents the optimal degree of transparency when the central bank attributes a larger weight to price deviations, with the following parameter values: $\sigma_g^2 = 1$, $\sigma_\eta^2 = 0.5$, and $\lambda = 0.25$. Partial transparency is optimal here for larger intervals of parameters than when the central bank equally weights price and output gap stabilisation. A low degree of transparency reduces firms' reaction to the instrument, which allows better price level stabilisation. However, full transparency is always optimal for the most plausible cases where the central bank's information is more precise than that of firms and where the degree of strategic complementarities is not too low ($\xi < 0.35$).

In summary, in the realistic case where firms' uncertainty is relatively high, the above analysis shows that full transparency is optimal when the economy is affected by demand shocks that the central bank tries to neutralise, as long as the latter is not too much oriented towards output gap stabilisation. This result differs from that of CORNAND and HEINEMANN [2008]. They show – in a framework very close to that of MORRIS and SHIN [2002] – that reducing the degree of common knowledge (with limited publicity) can improve welfare, even in some cases where the central bank's information is more precise than firms' private information. In this article, we show (in the case where the central bank's information is relatively more precise) that full transparency is optimal. This difference in results comes from the fact that the present framework accounts for the action of the central bank. Taking the central bank's action into account makes full transparency beneficial in so far as firms consider the monetary instrument, which reduces the distortion of the economy.

VI Conclusion

This paper analyses the welfare effects of economic transparency in the conduct of monetary policy under imperfect common knowledge on the demand shocks affecting the economy. The main characteristic of our approach is to recognise the dual role of monetary policy: the instrument of the central bank is both an action that stabilises the economy and a signal that (partly) reveals to firms the central bank's view of the fundamental state of the economy. We determine the optimal monetary policy and disclosure strategy of the central bank.

The presence of information imperfection gives rise to a trade-off for the central bank between its will to stabilise demand shocks and its will not to distort the economy with its instrument. By revealing its own estimate on the fundamental state to firms, a transparent central bank favours firms' reaction to the monetary instrument. The welfare effect of transparency is ambiguous and depends both on the weight attributed to output gap stabilisation and on the degree of fundamental and strategic uncertainty of firms. Transparency is detrimental to welfare either when the central bank strongly weights price level stabilisation and the degree of uncertainty of firms is low or when the central bank strongly weight output gap stabilisation and the degree of uncertainty of firms is high. However, we show that for realistic parameter values, transparency is beneficial as long as the central bank does not put too much weight on output gap stabilisation.

Our approach provides an additional argument in favour of transparency, by relying on monetary policy effectiveness to stabilise the economy. We therefore give a rationale for the recent evolution of central bank towards an increased transparency in the conduct of monetary policy that does not rely on democratic accountability considerations but rather on monetary policy effectiveness criteria in response to the demand shocks that characterise contemporary economies.

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References

Adam, Klaus (2007): "Optimal Monetary Policy with Imperfect Common Knowledge", *Journal of Monetary Economics*, Vol. 54(2), p. 276-301.

Amato, Jeffery D. and Huyn S. Shin (2006): "Imperfect Common Knowledge and the Information Value of Prices", *Economic Theory*, Vol. 27(1), p. 213-241.

Angeletos, George-Marios, and Alessandro Pavan (2007a): "Efficient Use of Information and Social Value of Information", *Econometrica*, Vol. 75(4), p. 1103-1142.

Angeletos, George-Marios, and Alessandro Pavan (2007b): "Socially Optimal Coordination: Characterization and Policy Implications", *Journal of the European Economic Association*, Vol. 5(2-3), p. 585-593.

Atkeson, Andrew (2001): "Discussion of Morris and Shin's 'Rethinking Multiple Equilibria in Macroeconomic Modelling'", in *NBER Macroeconomics Annual 2000*, ed. by B.S. Bernanke and K. Rogoff, The MIT Press.

Baeriswyl, Romain (2007): "Central Bank's Action and Communication", *Munich Discussion Paper* No. 2007-10.

Baeriswyl, Romain (2011): "Endogenous Central Bank Information and the Optimal Degree of Transparency", forthcoming in *International Journal of Central Banking*.

Baeriswyl, Romain, and Camille Cornand (2010a): "Optimal Monetary Policy in Response to Cost-Push Shocks: the Impact of Central Bank Communication", *International Journal of Central Banking*, Vol. 6(2), p. 31-52.

Baeriswyl, Romain, and Camille Cornand (2010b): "The Signaling Role of Policy Actions", *Journal of Monetary Economics*, Vol. 57(6), p. 682-695.

Bank of England (2005), *Inflation Report*, August.

Barro, Robert J., and David B. Gordon (1983): "A Positive Theory of Monetary Policy in a Natural Rate Model", *Journal of Political Economy*, Vol. 91(4), p. 589-610.

Blinder, Alan S. (1998): *Central Banking in Theory and Practice*, Cambridge, MA: MIT Press.

Clarida, Richard, Jordi Gali, and Mark Gertler (1999): "The Science of Monetary Policy: A New Keynesian Perspective", *Journal of Economic Literature*, Vol. 37(4), p. 1661-1707.

Cornand, Camille, and Frank Heinemann (2008): "Optimal Degree of Public Information Dissemination", *The Economic Journal*, Vol. 118, F718-742.

Cukierman, Alex (2001): "Accountability, Credibility, Transparency and Stabilization Policy in the Euro-System", in *The Impact of EMU on Europe and the Developing Countries*, ed. by C. Wyplosz, Oxford University Press, Oxford.

Geraats, Petra M. (2002): "Central Bank Transparency", *The Economic Journal*, Vol. 112, F532-F565.

Gersbach, Hans (2003): "On the Negative Social Value of Central Banks' Knowledge Transparency", *Economics of Governance*, Vol. 4(2), p. 91-102.

Hellwig, Christian (2002): "Public Announcements, Adjustment Delays and the Business Cycle", mimeo, November.

Hellwig, Christian (2005): "Heterogeneous Information and the Welfare Effects of Public Information Disclosures", mimeo, November.

Lucas, Robert E.J. (1972): "Expectations and the Neutrality of Money", *Journal of Economic Theory*, Vol. 4, p. 103-124.

Mankiw, N. Gregory, and Ricardo Reis (2002): "Sticky information versus sticky prices: A proposal to replace the new keynesian phillips curve", *Quarterly Journal of Economics*, Vol. 117, p. 1295-1328.

Morris, Stephen, and Hyun S. Shin (2002): "Social Value of Public Information", *American Economic Review*, Vol. 92(5), p. 1521-1534.

Morris, Stephen, and Hyun S. Shin (2005): "Central Bank Transparency and the Signal Value of Prices", *Brookings Papers on Economic Activity*, Vol. 2, p. 1-66.

Morris, Stephen, Hyun S. Shin, and Hui Tong (2006): "Reply to 'Social Value of Public Information: Morris and Shin (2002) is Actually Pro Transparency Not Con'",

American Economic Review, Vol. 96(1), p. 453-455.

Peek, Joe, Eric S. Rosengren, and Geoffrey M. B. Tootell (1999): "Is Bank Supervision Central to Central Banking?", *Quarterly Journal of Economics*, Vol. 114(2), p. 629-653.

Phelps, Edmund S. (1970): "Introduction: The New Microeconomics in Employment and Inflation Theory", in *Microeconomic Foundations of Employment and Inflation Theory*, 1-23, Norton, New York.

Poole, William (2005): "Remarks: Panel on 'After Greenspan: Whither Fed Policy?'", The Federal Reserve Bank of St. Louis, Western Economic Association International Conference, San Fransisco, July.

Romer, Christina D., and David H. Romer (2000): "Federal Reserve Information and the Behavior of Interest Rates", *American Economic Review*, Vol. 90(3), p. 429-457.

Svensson, Lars E.O. (2006): "Social Value of Public Information: Morris and Shin (2002) Is Actually Pro Transparency, Not Con", *American Economic Review*, Vol. 96, p. 448-451.

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

Walsh, Carl E. (2007): "Optimal Economic Transparency", *International Journal of Central Banking*, Vol. 3(1), p. 5-36.

Woodford, Michael (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. by P. Aghion, R. Frydman, J. Stiglitz and M. Woodford, Princeton University Press, Princeton.

Woodford, Michael (2005): "Central Bank Communication and Policy Effectiveness", mimeo.