Private News and Monetary Policy

Forward Guidance or (The Expected Virtue of Ignorance)*

Ippei Fujiwara† — *Keio University / ANU*

Yuichiro Waki‡ — *University of Queensland*

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Abstract

How should monetary policy be designed when the central bank has private information about future economic conditions? In a canonical new Keynesian model, a central bank that aims to stabilize inflation and the output gap finds it optimal to commit to not revealing these private news at all. There exists the *expected virtue of ignorance*, and secrecy or "ignorance is bliss" constitutes optimal policy. This result holds when news are about cost-push shocks, or about shocks to the monetary policy objective, or about shocks to the natural rate of interest, and even when the zero lower bound of nominal interest rates is taken into account. We also demonstrate through numerical examples that the same result holds for richer models too. A lesson of our analysis for a central bank's communication strategy is that *Delphic forward guidance* that helps the private sector form more accurate forecast for future shocks can be undesirable and the central bank should instead aim to communicate its state-contingent policy.

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†Faculty of Economics, Keio University, Tokyo, Japan. Crawford School of Public Policy, Australian National University, Canberra, Australia. Email: ippei.fujiwara@keio.jp

‡School of Economics, University of Queensland, Brisbane, Australia. Email: y.waki@uq.edu.au

1 Introduction

Central banks have been thought to possess private information about future economic conditions. Romer and Romer (2000) provide empirical evidence of asymmetric information between the central bank and private agents: "the Federal Reserve has considerable information about inflation beyond what is known to commercial forecasters.[1]" The presence of such superior information on the part of the central bank raises several questions. How should monetary policy be designed when the central bank has private information about future economic conditions? Is it welfare-improving if the central bank attempts to manage the private sector's expectation by communicating such information?

This paper investigates whether central banks should reveal such *private news* upon receipt and react appropriately, by adding news about future economic conditions to an otherwise standard new Keynesian model as in Woodford (2003), Galí (2008) or Walsh (2010). Future economic conditions we consider include future cost-push shocks, future shocks to the policy objective, and the future natural rate shocks at the zero lower bound of nominal interest rates. New Keynesian models are the best suited for our analysis, because the private sector is forward-looking and thus the central bank can manage expectations by conveying its private news, and because they are widely used in central banks to guide policies.

Answering this question is of practical relevance. Campbell, Evans, Fisher, and Justiniano (2012) distinguish between *Delphic forward guidance*, which involves public statements about "a forecast of macroeconomic performance and likely or intended monetary policy actions based on the policymaker's potentially superior information about future macroeconomic fundamentals and its own policy goals", and *Odyssean* forward guidance that involves the policy-maker's commitment. The empirical evidence they found suggests that the forward guidance employed by the FOMC have "a substantial

[1] Fujiwara (2005) shows that central bank forecasts significantly affect those by professional forecasters.

Delphic component". Understanding how the central bank should conduct *Delphic* forward guidance is therefore important, and this paper sheds light on this issue using a formal economic model.

Our main theoretical result is that, when the central bank aims to stabilize inflation and the output gap, it finds it optimal to commit to not revealing its superior information to the private sector at all in a canonical new Keynesian model. The ex-ante loss for the central bank increases whenever the private sector becomes better informed about future economic conditions. In other words, there exists the *expected virtue of ignorance*, and "ignorance is bliss" constitutes optimal monetary policy. In showing this result we only exploit the (log-)linearity of the environment and strict convexity of the central bank's loss function, but do not assume specific forms of information revelation from the central bank. Thus, this result also holds true in more general (log-)linear DSGE models, as far as no endogenous state variables are present.

The mechanism behind this result is simple. Because future inflation naturally depends on realization of future shocks, when the private sector becomes better informed about these shocks, its inflation expectations become more volatile, varying with anticipated future shocks. This increased volatility in inflation expectations acts as an additional source of disturbance in the new Keynesian Phillips curve, translates into higher variability of inflation and the output gap, and therefore it is harmful to the central bank who aims to stabilize these two variables.

Our result of the optimality of "ignorance is bliss" remains true for other important cases where the central bank possesses private news about the policy objective or the natural rate of interest with the binding zero lower bound of nominal interest rates. Under the zero lower bound constraint, previous studies have shown that raising inflation expectation improves welfare. Surprisingly, however, our theoretical result suggests that the central bank finds it optimal to commit to being secretive even if it knows it may receive such private news that a negative natural rate shock disappears in near future. The reason is that inflation expectation of a better-informed private sector is more dispersed and thus can be lower than that of a less informed private sector. From the ex-ante point of view, additional loss when inflation expectation decreases outweigh additional gains when inflation expectation increases, thereby making secrecy optimal even at the zero lower bound.

To understand more precisely how the central bank's ability is constrained when faced with a better informed private sector, we numerically solve for the optimal monetary policy when the private sector observes n-period ahead cost-push shocks, assuming that the central bank is benevolent. Impulse response analysis suggests that, when the central bank can commit, inflation response becomes generally more smoothed but the response of marginal cost becomes more magnified, as the private sector becomes more informed (n is raised). We also find that gains from commitment become larger as the private sector becomes more informed. Robustness checks are also conducted by examining two models with endogenous state variables — the model with price indexation by Steinsson (2003) and the model with endogenous capital formation by Edge (2003) and Takamura, Watanabe, and Kudo (2006) — and a nonlinear, canonical new Keynesian model with Calvo price setting. We find that even in these models, the central bank finds it optimal to commit to secrecy.

The reason for smoothed response of inflation and magnified response of marginal cost under commitment is closely related to the mechanism behind the undesirability of information revelation. When the private sector is better informed about future cost-push shocks, the central bank finds it optimal to reduce the dispersion in inflation expectation by reducing the dependence of future inflation on foreseen shocks, and this is done only at the cost of increased variations in the marginal costs. Inability to commit results in greater loss because the central bank that cannot commit is unable to lower the dispersion in inflation expectation, which increases as the private sector becomes more informed.

This study therefore points to an interesting property of a wide range of (log-)linear new Keynesian models. Although these models are forward-looking, providing more accurate forecast about future fundamental shocks and responding pre-emptively to these shocks reduce social welfare. This implication provides a cautionary tale for the use of communication by the central bank. For example, importance of *management of expectations* or forward guidance has been very often emphasized in the new Keynesian policy literature (Woodford, 2003), and also in the real world policy-making after many central banks in advanced economies reduced short-term nominal interest rates to the lowest possible level in response to the recent financial crisis.[2] Our result suggests that it may be socially undesirable if the central bank, through communication, helps the private sector form more accurate forecast for future economic conditions. *Delphic* forward guidance based on private news can be detrimental to social welfare. The central bank should instead aim to conduct *Odyssean* forward guidance: communicating its state-contingent policy, i.e. what it will do in response to these shocks after they materialize.

This paper is structured as follows. Section 2 provides the baseline setting and the main theorem about the undesirability of information revelation. In Section 3 we conduct numerical analysis for the baseline model as well as for extended models with backward price indexation or with endogenous capital formation. Section 4 concludes.

1.1 Related literature

Whether a central bank should disclose its private information to the public or not is not a new question, but our study is unique in its focus on the role of news shocks in a dynamic setting. There have been vast studies, including Morris and Shin (2002) and Angeletos and Pavan (2007), that discuss the *pros* and *cons* about the enhanced dissemination of information by the central banks. These studies focus on the role of the central bank's disclosure policy in coordinating actions of private agents that

[2]Forward guidance is not necessarily a policy prescription under liquidity trap. Svensson (2014) states that "for many years, some central banks have used forward guidance as a natural part of their normal monetary policy." Its usefulness has been reported even in normal time.

are heterogeneously informed about contemporaneous economic conditions, and mainly on static settings.[3] Increased precision of a public signal can reduce welfare in these studies, but the reason is the coordination motives. In contrast, there is neither dispersed information among private agents nor a need for coordinating their actions in our model, but information revelation is still detrimental to welfare.[4]

Stein (1989) and Moscarini (2007) are also important precursors of our research. In their model the central bank has private information about its policy goals, but it is not a news shock. By setting up a cheap-talk game (Crawford and Sobel, 1982) which explicitly models communication by the central bank, they show that, although full information revelation is desirable, only imperfect communication is possible in an equilibrium, thereby providing a theory of imprecise announcement from policy-makers. Moscarini (2007) further shows that the more precise signal the central bank observes, the more information is revealed and the higher welfare is achieved. Our paper, by focusing on private news shocks, shows that their conclusion does not apply to news shocks: information revelation is not desirable in the first place.

This paper is also related to the literature of news shocks that finds news shocks are important in accounting for business cycle fluctuations, including Beaudry and Portier (2006, 2014), Jaimovich and Rebelo (2009), Fujiwara, Hirose, and Shintani (2011) or Schmitt-Grohé and Uribe (2012). While these papers largely focus on technology shocks and assume symmetric information between the central bank and the private sector, departing from complete information is important because it allows us to discuss how the central bank should communicate its information. To the best of our knowledge, this is the first paper to explore optimal information revelation policy to the news shock in

[3] An exception is Hellwig (2005) that considers a dynamic general equilibrium model in which price setters are heterogeneously informed about the contemporaneous money supply.

[4] Svensson (2006) argues that the welfare-reducing property of increased precision of the public signal is rather limited to a small region of the parameter space in the model of Morris and Shin (2002). In our model, the undesirability of information revelation is a global property.

a prototypical new Keynesian model.[5]

2 Theoretical results

We begin by setting up our baseline model in which the central bank is more informed about future cost-push shocks than does the private sector and in which the central bank benefits from stabilizing inflation and the output gap. The question we ask is, does the central bank find it beneficial to commit to making the private sector better-informed about future cost-push shocks? We find that the answer to this question is no, regardless of the way the central bank reveals information to the private sector. Therefore, the optimal commitment policy never reveals or exploits superior information the central bank possesses. This result holds even when the central bank possesses private news about the policy objective or the natural rate of interest with the binding zero lower bound of nominal interest rates. We also discuss how the result extends to a situation in which the central bank cannot commit.

In answering this question, we do not assume specific channels through which the private information of the central bank is conveyed to the private sector: The central bank may be able to send costless messages as in e.g. Stein (1989) and Moscarini (2007); The private sector may infer the central bank's private information from the central bank's actions that depend on its private information as in e.g. Cukierman and Meltzer

[5]Bianchi and Melosi (2014) compares transparency and no transparency when the monetary policy follows a Taylor rule whose coefficients change according to a Markov chain. Because they find welfare gains from transparency, we compare our paper with theirs in details in Section 2.5.

Lorenzoni (2010) explores optimal monetary policy when aggregate fluctuations are driven by the private sector's uncertainty about the economy's fundamentals. Contrary to our simple framework, however, information on aggregate productivity is dispersed across private agents.

Gaballo (2013) scrutinizes whether the central bank should release its information about future economic conditions in a flexible price OLG model. His model is close to Morris and Shin (2002) in that the central bank's announcement is perceived heterogeneously among households due to idiosyncratic noise. In contrast, our analysis is based on a standard model for monetary policy analysis, and the model is much simpler.

Christiano, Ilut, Motto, and Rostagno (2010) explores the Ramsey optimal monetary policy to the news shock, but there exists no private information.

(1986).

Proofs are simple and based on Jensen's inequality, exploiting the linearity of the new Keynesian Phillips curve and the strict convexity of the loss function.[6] Therefore, the result of the desirability of secrecy about future fundamental shocks holds true in more general, linearized DSGE models without endogenous state variables. After presenting our theoretical results, we demonstrate through numerical experiments that the desirability of secrecy holds in some models with state variables, such as those with backward price indexation and with endogenous capital accumulation.

2.1 Environment

We employ the standard analytical framework for optimal monetary policy as in Woodford (2003), Galí (2008) or Walsh (2010).

Stochastic processes for inflation $\{\pi_t\}_{t=0}^{\infty}$ and the output gap $\{x_t\}_{t=0}^{\infty}$ have to satisfy the aggregate supply relationship, or the new Keynesian Phillips curve:

$$\pi_t = \beta \mathbb{E}_t^P \pi_{t+1} + \kappa x_t + u_t, \tag{1}$$

where $\mathbb{E}_t^P$ denotes the expectation conditional on the information available to the private sector (hence the superscript P) in period t, and u_t is a cost-push (mark-up) shock. This cost-push shock is distortionary, and creates the time-varying wedge between actual and efficient allocations.[7]

The central bank's ex-ante loss function is given by

$$\mathbb{E}[\sum_{t=0}^{\infty} \delta^t L(\pi_t, x_t)], \tag{2}$$

[6] Linearity is stronger than we need. A sufficient condition for our result is that the constraint set of the Ramsey problem is convex.

[7] When instead non-distortionary shocks hit the economy, any distortion caused by such shocks can be eliminated by appropriate and instantaneous responses by the central bank. There is no need for pre-emptive action to news on non-distortionary shocks.

where L be a strictly convex, momentary loss function and $\delta \in (0, 1)$ is the discount factor. This loss function represents the idea that the central bank pursues some kind of "dual mandate" — the central bank benefits from stabilizing inflation and the output gap. We do not rule out the situation that the central bank is benevolent: this specification indeed nests the social welfare loss that is obtained as the second-order approximation of the representative household's utility in a Calvo-type sticky price model, when $\delta = \beta$ and

$$L(\pi, x) = \frac{1}{2}\left(\pi^2 + \frac{\kappa}{\epsilon}x^2\right), \tag{3}$$

where ϵ denotes the CES parameter for intermediate goods.[8]

For now we assume that the only fundamental shock that hits the economy is the cost-push shock, $\{u_t\}_{t=0}^{\infty}$.[9] Its precise nature does not affect our theoretical results, and thus we do not impose any particular structure.[10] The private sector observes at least contemporaneous cost-push shocks, and thus is originally (i.e. before any information is revealed from the central bank) endowed with a filtration $\mathcal{F} = \{\mathcal{F}_t\}_{t=0}^{\infty}$ such that $\{u_t\}_{t=0}^{\infty}$ is adapted to it.[11] This allows that the private sector also observes informative signals about future cost-push shocks. The central bank is endowed with a filtration that is finer than $\mathcal{F}$, which implies that the central bank has more information than does the private sector, but its superior information is only about future shocks.

[8]This approximation obtains when the steady-state distortion associated with monopolistic competition is offset by a tax or subsidy, with x denoting the welfare relevant output gap.

[9]In section 2.4 we extend the model to incorporate other shocks.

[10]The only restriction is that the loss minimization problem which we introduce shortly must be well-defined. This rules out e.g. a shock process that grows too quickly.

[11]This is not crucial. Because in a micro-founded model u_t is a shock to the firm's profit function (or more specifically to the elasticity of substitution), if we instead assume that the price setters do not know it when setting prices, we should have $\mathbb{E}[u_t|\mathcal{F}_t]$ in place of u_t in the new Keynesian Phillips curve. Then the process $\{\mathbb{E}[u_t|\mathcal{F}_t]\}_{t=0}^{\infty}$ is $\mathcal{F}$-adapted.

2.2 An illustrative, two-period model

Before showing it formally, we first illustrate why the central bank finds it optimal to commit to being secretive about private news using a stripped-down model.To focus on the effects of information provision, consider a two-period version of the economy presented above in which the output gap is absent and inflation rates are solely driven by exogenous shocks and by the private sector's expectation about a future shock. We do this by setting $\kappa = 0$. The central bank is benevolent and minimizes the ex-ante social loss in (3) with $\kappa = 0$:

$$\frac{1}{2}\mathbb{E}\left[\pi_0^2 + \pi_1^2\right],$$

where, for simplicity of analysis, we assume that $\beta = 1$. The new Keynesian Phillips curve is given by

$$\pi_0 = \mathbb{E}^P \pi_1 + u_0,$$

$$\pi_1 = u_1.$$

In this example we assume that u_0 and u_1 are iid random variables with mean zero and variance σ_u^2. The central bank observes both (u_0, u_1) at the beginning of period 0, but the private sector observes u_1 only in period 1.

In this setting, the central bank can affect social welfare if it can credibly reveal its superior information to the private sector. Imagine that the central bank, *before* observing the private news, has only two options. It can commit either to being completely secretive about this news or to revealing them fully and credibly. The question is, which option does the central bank prefer?

Perhaps surprisingly, the benevolent central bank finds it optimal to commit to being secretive. When the central bank chooses to commit to being secretive, the private sector's inflation expectation is zero, $\mathbb{E}^P \pi_1 = 0$, and the new Keynesian Phillips curve implies $\pi_0 = u_0$. The ex-ante welfare loss under secrecy is thus

$$\mathbb{E}\left[u_0^2 + u_1^2\right]/2 = \sigma_u^2.$$

If the central bank commits to revealing its private news, the private sector knows u_1 when forming inflation expectations. Therefore $\mathbb{E}^P \pi_1 = u_1$ and the new Keynesian Phillips curve implies $\pi_0 = u_0 + u_1$. The ex-ante welfare loss under full information revelation is now given by

$$\mathbb{E}[(u_0 + u_1)^2 + u_1^2]/2 = 1.5\sigma_u^2,$$

which is strictly larger than the loss under secrecy, σ_u^2.

In this simple example, the revelation of the future shock only increases the volatility of inflation expectations and, therefore, that of inflation in period 0. Thus, no revelation of future cost-push shock is better than full revelation. This mechanism is at work in our general setting too, as we show in the next section.

2.3 Undesirability of information revelation with commitment

Now we turn to the original, general setting to demonstrate that information revelation is undesirable. We first consider the case where the central bank can commit. A benchmark is an optimal commitment policy when the private sector's filtration is unchanged from $\mathcal{F}$ and the central bank chooses inflation and the output gap processes that are $\mathcal{F}$-adapted. We say that $\{(\pi_t^*, x_t^*)\}_{t=0}^{\infty}$ is an *optimal secretive commitment policy* if it solves

$$\min_{\{(\pi_t, x_t)\}_{t=0}^{\infty}} \mathbb{E}[\sum_{t=0}^{\infty} \delta^t L(\pi_t, x_t)] \tag{4}$$

subject to

$$\pi_t = \kappa x_t + \beta \mathbb{E}[\pi_{t+1}|\mathcal{F}_t] + u_t, \tag{5}$$

and the constraint that the process $\{(\pi_t, x_t)\}_{t=0}^{\infty}$ is adapted to $\mathcal{F}$.[12]

Lemma 1 *The optimal secretive commitment policy is unique (almost everywhere) if it exists.*

This lemma immediately follows from the strict convexity of the objective function and the linearity of the constraint. In the following we assume that an optimal secretive commitment policy exists.

Because the central bank is better informed about the future cost-push shocks than is the private sector, it is natural to ask whether the central bank benefits from revealing some information to the private sector. One possible approach is to specify a setting in which the central bank's private information is revealed, either costly or costlessly, either perfectly or imperfectly, through a particular channel, e.g. through direct communication or through the private sector's inference from the central bank's actions, and to investigate the best equilibrium in that setting. However, whether information revelation is good or not may depend crucially on a specific information transmission channel. Therefore, we take a more agnostic approach to provide a clear answer to this question.

Our approach is simple. In any reasonable equilibrium concept in these settings where the central bank reveals information to the private sector in one way or another, equilibrium stochastic processes for inflation and the output gap must satisfy the new Keynesian Phillips curve. There, inflation expectation is conditional on a filtration that is potentially finer than what the private sector is originally endowed. We show that such processes cannot reduce the central bank's loss from the loss achieved by the optimal

[12] Because the optimal secretive commitment policy is $\mathcal{F}$-adapted, the private sector is unable to obtain more information than contained in $\mathcal{F}$, by observing inflation, the output gap, and the nominal interest rate. The constraint that the policy must be $\mathcal{F}$-adapted is actually not binding. See Appendix A.3.

secretive policy. We also show that, when the private sector's information is improved in a way that its inflation forecast becomes better, the central bank's loss is strictly increased.

The following lemma shows that the presence of a better informed private sector does not reduce the central bank's loss.

Lemma 2 *Let $\mathcal{G} = \{\mathcal{G}_t\}_{t=0}^{\infty}$ be a filtration such that $\mathcal{F}_t \subset \mathcal{G}_t$ for all t. Then, for any process $\{(\pi_t, x_t)\}_{t=0}^{\infty}$ that is $\mathcal{G}$-adapted and satisfies*

$$\pi_t = \kappa x_t + \beta \mathbb{E}[\pi_{t+1}|\mathcal{G}_t] + u_t, \quad \forall t, \tag{6}$$

there is a process $\{(\tilde{\pi}_t, \tilde{x}_t)\}_{t=0}^{\infty}$ such that (i) it is adapted to $\mathcal{F}$, (ii) it satisfies

$$\tilde{\pi}_t = \kappa \tilde{x}_t + \beta \mathbb{E}[\tilde{\pi}_{t+1}|\mathcal{F}_t] + u_t, \quad \forall t, \tag{7}$$

and (iii)

$$\mathbb{E}[L(\pi_t, x_t)] \geq \mathbb{E}[L(\tilde{\pi}_t, \tilde{x}_t)], \quad \forall t. \tag{8}$$

Equality holds in (8) if and only if $(\pi_t, x_t) = (\tilde{\pi}_t, \tilde{x}_t)$ almost everywhere for all t.

Proof. Proof is by construction. Fix any $\{(\pi_t, x_t)\}_{t=0}^{\infty}$ that is adapted to $\mathcal{G}$ and satisfies (6). Let

$$(\tilde{\pi}_t, \tilde{x}_t) = (\mathbb{E}[\pi_t|\mathcal{F}_t], \mathbb{E}[x_t|\mathcal{F}_t]).$$

Then $\{(\tilde{\pi}_t, \tilde{x}_t)\}_{t=0}^{\infty}$ is adapted to $\mathcal{F}_t$. Taking the conditional expectation of (6) given $\mathcal{F}_t$, we obtain

$$\tilde{\pi}_t = \kappa \tilde{x}_t + \beta \mathbb{E}[\pi_{t+1}|\mathcal{F}_t] + u_t.$$

Because $\mathbb{E}[\pi_{t+1}|\mathcal{F}_t] = \mathbb{E}\left[\mathbb{E}[\pi_{t+1}|\mathcal{G}_t]|\mathcal{F}_t\right] = \mathbb{E}[\tilde{\pi}_{t+1}|\mathcal{F}_t]$, this implies (7).

Jensen's inequality implies

$$\mathbb{E}[L(\pi_t, x_t)] = \mathbb{E}\left[\mathbb{E}[L(\pi_t, x_t)|\mathcal{F}_t]\right] \geq \mathbb{E}\left[L(\mathbb{E}[\pi_t|\mathcal{F}_t], \mathbb{E}[x_t|\mathcal{F}_t])\right] = \mathbb{E}[L(\tilde{\pi}_t, \tilde{x}_t)],$$

for all t, and it follows that, because L is strictly convex, equality holds for all t if and only if $\{(\pi_t, x_t)\}_{t=0}^{\infty} = \{(\tilde{\pi}_t, \tilde{x}_t)\}_{t=0}^{\infty}$ almost everywhere. ■

An implication of Lemma 2 is that endowing the private sector with larger filtration never reduces the central bank's loss for *any* discount factor $\delta \in (0, 1)$ because (8) holds for period by period. The reason is that fluctuations in a stochastic process adapted to a larger filtration can be, roughly speaking, reduced by taking the conditional expectation using a smaller filtration, and that the strictly convex loss function favors processes that fluctuate less. From the central bank's point of view, it is at best meaningless to help the private sector learn more information.

We now identify a condition under which the central bank's loss under information revelation is strictly higher than that of the optimal secretive commitment policy.

Proposition 1 *Let $\mathcal{G} = \{\mathcal{G}_t\}_{t=0}^{\infty}$ be a filtration such that $\mathcal{F}_t \subset \mathcal{G}_t$ for all t. If the optimal secretive commitment policy satisfies*

$$\textit{Probability of } \left\{\mathbb{E}[\pi_{t+1}^*|\mathcal{G}_t] \neq \mathbb{E}[\pi_{t+1}^*|\mathcal{F}_t] \textit{ for some } t\right\} > 0,$$

then the loss from $\{(\pi_t^*, x_t^*)\}_{t=0}^{\infty}$ is strictly smaller than that from any $\mathcal{G}$-adapted processes $\{(\pi_t, x_t)\}_{t=0}^{\infty}$ that satisfy the new Keynesian Phillips curve in (6).

Proof. Let $\{(\pi_t, x_t)\}_{t=0}^{\infty}$ be a $\mathcal{G}$-adapted process which satisfies (6), and define $\{(\tilde{\pi}_t, \tilde{x}_t)\}_{t=0}^{\infty}$ as in Lemma 2. If $\{(\pi_t, x_t)\}_{t=0}^{\infty}$ is not $\mathcal{F}$-adapted, then it follows that

$$\mathbb{E}[\sum_{t=0}^{\infty} \delta^t L(\pi_t, x_t)] > \mathbb{E}[\sum_{t=0}^{\infty} \delta^t L(\tilde{\pi}_t, \tilde{x}_t)] \geq \mathbb{E}[\sum_{t=0}^{\infty} \delta^t L(\pi_t^*, x_t^*)].$$

If $\{(\pi_t, x_t)\}_{t=0}^{\infty}$ is $\mathcal{F}$-adapted, then $\{(\pi_t^*, x_t^*)\}_{t=0}^{\infty} \neq \{(\pi_t, x_t)\}_{t=0}^{\infty}$, because $\{(\pi_t^*, x_t^*)\}_{t=0}^{\infty}$ does not satisfy (6) under the stated conditions while $\{(\pi_t, x_t)\}_{t=0}^{\infty}$ does. Because the an optimal secretive commitment policy is unique (Lemma 1), it follows that

$$\mathbb{E}[\sum_{t=0}^{\infty} \delta^t L(\pi_t, x_t)] = \mathbb{E}[\sum_{t=0}^{\infty} \delta^t L(\tilde{\pi}_t, \tilde{x}_t)] > \mathbb{E}[\sum_{t=0}^{\infty} \delta^t L(\pi_t^*, x_t^*)].$$

■

When the condition identified in Proposition 1 holds, the optimal secretive commitment policy violates the new Keynesian Phillips curve in (6) with positive probability. Therefore a process that satisfies (6) cannot be equal to the optimal secretive policy almost everywhere, and its loss must be strictly higher than that of the optimal secretive policy.

The condition stated in Proposition 1 is not strong. Suppose that the private sector only observes the contemporaneous u's, that the central bank observes future u's, and that the central bank is able to communicate credibly that information to the private sector. Let $\mathcal{G}$ be the filtration for the private sector after such communication. Then u_{t+1} is not $\mathcal{F}_t$-measurable but is $\mathcal{G}_t$-measurable. When the loss function is quadratic, the an optimal secretive commitment policy linearly depends on a contemporaneous shock. This naturally implies

$$\mathbb{E}[\pi_{t+1}^* | \mathcal{G}_t] \neq \mathbb{E}[\pi_{t+1}^* | \mathcal{F}_t],$$

because the left hand side depends on u_{t+1} but the right hand side does not.[13] Moreover, when the condition identified in Proposition 1 is not satisfied, the private sector is effectively not learning anything useful — new information it obtains doesn't help predicting the future inflation (under the optimal secretive commitment policy) any better.

[13] More generally, when $\mathcal{F}_{t+1} \subset \mathcal{G}_t$ for all t, we have $\mathbb{E}[\pi_{t+1}^* | \mathcal{G}_t] = \pi_{t+1}^*$, which does not equal $\mathbb{E}[\pi_{t+1}^* | \mathcal{F}_t]$ unless π_{t+1}^* is also $\mathcal{F}_t$-measurable.

2.3.1 Intuition

To obtain some intuition, let us assume that the central bank is benevolent and minimizes the loss in (3). Then the central bank benefits from stabilizing inflation and the output gap around zero.

Now rewrite (6) as

$$\pi_t - \kappa x_t = \underbrace{\{\beta \mathbb{E}[\pi_{t+1}|\mathcal{F}_t] + u_t\}}_{\text{“original” term}} + \underbrace{\beta\{\mathbb{E}[\pi_{t+1}|\mathcal{G}_t] - \mathbb{E}[\pi_{t+1}|\mathcal{F}_t]\}}_{\text{“updating” term}}. \tag{9}$$

Observe that the benevolent central bank benefits from stabilizing the right-hand side around zero, because it can then stabilize inflation and the output gap around zero. The right-hand side consists of two terms, the “original” term and the “updating” term. The former collects the terms that are present even when the private sector's information is given by $\mathcal{F}$, and the latter captures how inflation expectations are updated when the information set is changed from $\mathcal{F}_t$ to $\mathcal{G}_t$. Therefore, taking the stochastic process $\{\pi_t, x_t\}$ as given, the updating term represents the effects of information revelation.

The decomposition in (9) implies that the presence of the updating term increases the variability of the right-hand side, and hence that the social loss increases with information revelation. To see this, note that the original term is $\mathcal{F}$-adapted because cost-push shocks are F-adapted, whereas the updating term is orthogonal to $\mathcal{F}_t$. The variance of the right-hand side of (9) is thus the sum of those of the original and the updating terms, which is minimized when $\mathcal{F}_t = \mathcal{G}_t$. Roughly speaking, if $\mathcal{F}_t \subset \mathcal{G}_t$, the updating term effectively acts as an additional orthogonal disturbance term in the new Keynesian Phillips curve, which exacerbates the inflation-output tradeoff the central bank faces.

Figures 1 and 2 illustrate the point graphically. On the horizontal axis is $\pi_t - \kappa x_t$, which equals the sum of the discounted expected inflation and the mark-up shock, $\beta \mathbb{E}^P[\pi_{t+1}] + u_t$. We also draw the loss function L as a symmetric function around its

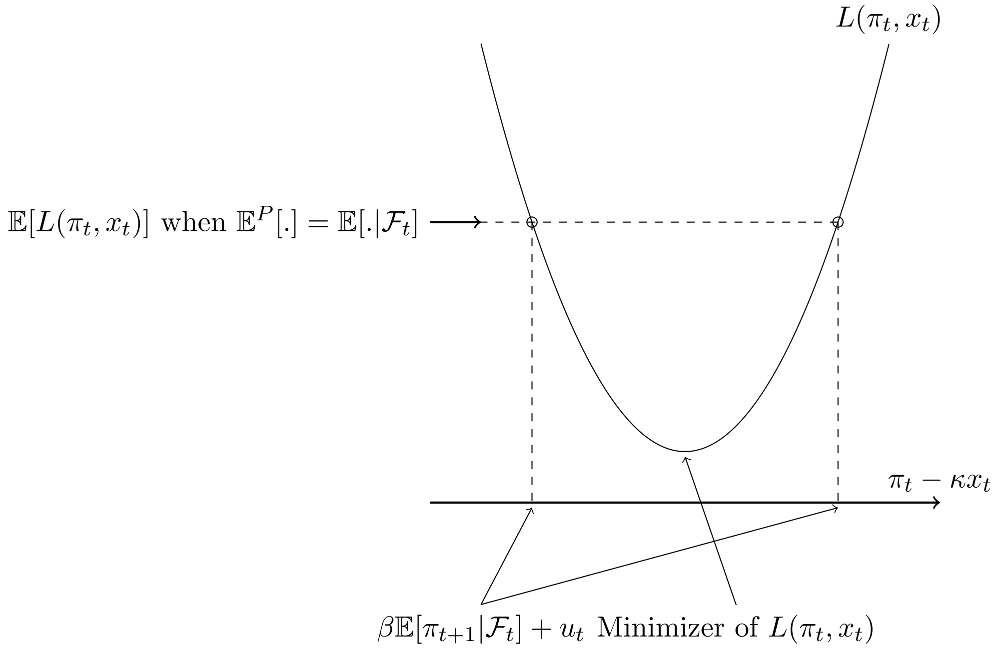

Figure 1: The inflation vs. the output gap trade-off when the private sector is uninformed

minimizer. Figure 1 illustrates a situation where the private sector is endowed with the $\mathcal{F}$ and the term $\beta\mathbb{E}[\pi_{t+1}|\mathcal{F}_t] + u_t$ can take on two values that are symmetric around the minimizer of L, with equal probability. Then it is straightforward that the ex-ante loss is at the level indicated in the figure. In Figure 2, the private sector is better informed, and is endowed with $\mathcal{G}$ with $\mathcal{F} \subset \mathcal{G}$. How is $\beta\mathbb{E}[\pi_{t+1}|\mathcal{G}_t] + u_t$ distributed? Because its conditional mean given $\mathcal{F}_t$ equals $\beta\mathbb{E}[\pi_{t+1}|\mathcal{F}_t] + u_t$, it must be distributed around $\beta\mathbb{E}[\pi_{t+1}|\mathcal{F}_t] + u_t$. Figure 2 depicts such a situation, where $\beta\mathbb{E}[\pi_{t+1}|\mathcal{G}_t] + u_t$ is distributed symmetrically around $\beta\mathbb{E}[\pi_{t+1}|\mathcal{F}_t] + u_t$. The ex-ante loss when the private sector is better informed is larger than that when the private sector is less informed. This implies that the distribution of $\pi_t - \kappa x_t$ when the private sector is better informed is a mean-preserving spread of that when the private sector is less informed. Because the loss function is convex, a mean-preserving spread is undesirable.

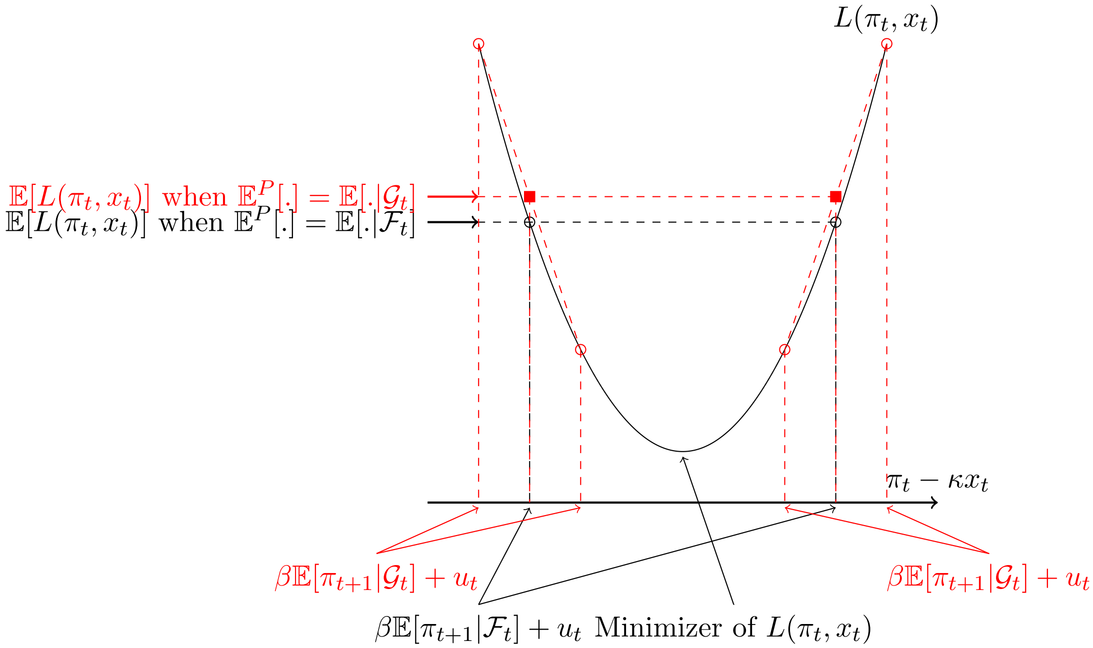

Figure 2: The inflation vs. the output gap trade-off when the private sector is better informed

2.3.2 Where do the gains from better information go?

When the private sector obtains more information, then it may appear that the private agents — both the household and the goods producers — must not lose anything because they can still choose not to use additional information. This assertion is incorrect, because the price setters' incentives are not perfectly aligned with the household's (i.e. social welfare) or with the central bank's.

Assume a benevolent central bank that minimizes the loss (3). Ideally, the central bank wants to conduct policy so that both inflation and the output gap are always zero. For any given process of inflation and any information the household has, the central bank can indeed conduct policy so that the output gap is always zero.[14] However, the price setters have incentives to deviate from price stability even if the output gap is fully stabilized at zero, when a mark-up shock and inflation expectation deviate from zero.

[14]The central bank can do this by choosing the process of the nominal interest rates so that the real rates are always equal to the natural rates.

In other words, social objective and the price setters' incentives are not aligned. This is the reason why the optimal commitment policy problem has to take the new Keynesian Phillips curve, which summarizes the price setters' incentives, as a constraint. When the price setters obtain more information about future shocks, they tailor their current prices based on an improved inflation forecast, and achieve higher profits.[15] However, as a result, prices then tend to move with future shocks and social welfare decreases.[16]

2.3.3 Ex-ante vs. time-0 expected loss

It is more common to use the expected discounted sum of losses conditional on the time-0 information, i.e. after the time-0 shocks have realized. We can replace the unconditional expectations in the above results with the conditional expectation based on $\mathcal{F}_0$ (the private sector's information set at time 0) if there is no information asymmetry between the central bank and the private sector when the central bank chooses its strategy. This condition is trivially satisfied when the central bank does not possess any private information at time 0, and is also satisfied when the central bank chooses how it will disclose information before it receives its time-0 private information. In other words, the central bank finds it suboptimal to resolve the information asymmetry that hasn't happened but will arise in the future.

[15] The price setters take certain prices as given, e.g. the aggregate nominal price, real wage, etc. Taking these prices as given, the profits of the price setters increase with information they possess. Because these objects change in an equilibrium, the price setters equilibrium profits may not increase.

[16] In other words, it is crucial that there are shocks that generate inefficient fluctuations. This is related to the finding in Angeletos and Pavan (2007), that "if business cycles are driven primarily by shocks in markups or other distortions that induce a countercyclical efficiency gap, it is possible that providing markets with information that helps predict these shocks may reduce welfare." They make this point using a stylized, static model with dispersed information within the private agents, while we show that it is also possible for news shocks in the canonical new Keynesian model without information asymmetry within the private sector.

2.4 Extensions

The main result so far even holds with private news on other information than cost-push shocks. We provide proof that secrecy is optimal even when the central bank possesses private news about the policy objective or the natural rate of interest with the binding zero lower bound of nominal interest rates.

2.4.1 A new Keynesian model with the zero lower bound

To demonstrate that our theoretical results easily extend to other linearized DSGE models, here we consider a model along the lines of Eggertsson and Woodford (2003) and Adam and Billi (2006), in which the zero lower bound on nominal interest rates can bind when a large, negative shock to the natural rate of interest hits the economy. Due to the non-negativity constraint on nominal interest rate,

$$i_t \geq 0, \tag{10}$$

we have to explicitly take into account the dynamic IS equation:

$$x_t = \mathbb{E}[x_{t+1}|\mathcal{F}_t] - \frac{1}{\sigma}\{i_t - \mathbb{E}[\pi_{t+1}|\mathcal{F}_t] - r_t^n\}. \tag{11}$$

In addition to the cost-push shock $\{u_t\}_{t=0}^{\infty}$, the natural rate of interest $\{r_t^n\}_{t=0}^{\infty}$ is also an $\mathcal{F}$-adapted stochastic process. Note, however, that we assume neither that the economy is at the zero lower bound at time 0, nor that the natural rate follows a two-state Markov chain with its steady-state value as the absorbing state. Therefore, this model allows for the zero lower bound to bind multiple times and for the central bank to act differently when it foresees the zero bound binds or it ceases to bind in near future.

An optimal secretive commitment policy is $\{(\pi_t^*, x_t^*, i_t^*)\}_{t=0}^{\infty}$ that minimizes the loss function (4) subject to the new Keynesian Phillips curve in (5), the dynamic IS equation in (11), and the non-negativity constraint in (10). Then the following proposition immediately holds.

Proposition 2 *Let $\mathcal{G} = \{\mathcal{G}_t\}_{t=0}^{\infty}$ be a filtration such that $\mathcal{F}_t \subset \mathcal{G}_t$ for all t. If the optimal secretive commitment policy $\{(\pi_t^*, x_t^*, i_t^*)\}_{t=0}^{\infty}$ satisfies*

$$\textit{Probability of } \Big\{\mathbb{E}[\pi_{t+1}^*|\mathcal{G}_t] \neq \mathbb{E}[\pi_{t+1}^*|\mathcal{F}_t] \textit{ for some } t\Big\} > 0,$$

or

$$\textit{Probability of } \left\{\mathbb{E}[x_{t+1}^*|\mathcal{G}_t] + \frac{1}{\sigma}\mathbb{E}[\pi_{t+1}^*|\mathcal{G}_t] < \mathbb{E}[x_{t+1}^*|\mathcal{F}_t] - \frac{1}{\sigma}\{i_t^* - \mathbb{E}[\pi_{t+1}^*|\mathcal{F}_t]\} \textit{ for some } t\right\} > 0,$$

then the loss from $\{(\pi_t^*, x_t^*, i_t^*)\}_{t=0}^{\infty}$ is strictly smaller than that from any $\mathcal{G}$-adapted processes $\{(\pi_t, x_t, i_t)\}_{t=0}^{\infty}$ that satisfy the new Keynesian Phillips curve in (6), the dynamic IS equation:

$$x_t = \mathbb{E}[x_{t+1}|\mathcal{G}_t] - \frac{1}{\sigma}\{i_t - \mathbb{E}[\pi_{t+1}|\mathcal{G}_t] - r_t^n\},$$

and the non-negativity constraint in (10).

The second condition identifies the situation in which expectations in the dynamic IS equation change so much that even lowering the nominal rate to zero is not sufficient to maintain the output gap at x_t^*.

This proposition implies that, from the ex-ante point of view, the central bank should be secretive even if the zero lower bound is binding and if it, for example, receives private news that a negative natural rate shock disappears in near future or that a future cost-push shock is positive. This might sound strange, because the literature has shown that raising inflation expectation can be welfare-improving at the zero lower bound. The reason behind this seemingly surprising result is simple. Imagine that the private sector becomes better-informed when the zero lower bound is binding. Then its inflation expectation becomes, from the ex-ante point of view, necessarily more dispersed around the original inflation expectation that is based on a coarser information set. This implies that there are situations in which inflation expectation is raised and the central bank's loss is lowered, but at the same time that inflation expectation is reduced and the central bank's loss is increased in other situations. In other words, the last term in (9) cannot be made always strictly positive. Because the loss function is convex, it is better in terms of the ex-ante loss to implement the average outcome by not making the private sector more informed.

2.4.2 Private news about the central bank's future policy goals

Delphic forward guidance can be used to talk not only about future distortionary shocks but also about the central bank's objective in the future. We can easily augment our baseline model with a shock that influences the central bank's loss. Let $\{\theta_t\}_{t=0}^{\infty}$ be an exogenous stochastic process, and the central bank's loss is now given by

$$\mathbb{E}\sum_{t=0}^{\infty}\delta^t L(\pi_t, x_t, \theta_t).$$

A quadratic example such as

$$L(\pi, x, \theta) = \frac{1}{2}\left[(\pi-\theta)^2 + bx^2\right], \quad b \geq 0, \tag{12}$$

is used elsewhere in the literature, e.g. Stein (1989), Moscarini (2007), Athey, Atkeson, and Kehoe (2005), and Waki, Dennis, and Fujiwara (2015).

Note that Lemma 2 and Proposition 1 hold true in this augmented model, under the assumption that $\{\theta_t\}_{t=0}^{\infty}$ is $\mathcal{F}$-adapted, i.e. the private sector observes contemporaneous θ.[17] This assumption is useful to isolate the effects of revealing private news about future

[17] Otherwise we are unable to obtain

$$\mathbb{E}[\mathbb{E}[V(\pi_t, x_t, \theta_t)|\mathcal{F}_t]] \geq \mathbb{E}[V(\mathbb{E}[\pi_t|\mathcal{F}_t], \mathbb{E}[x_t|\mathcal{F}_t], \theta_t)],$$

monetary policy objectives. Under this assumption, revealing future monetary policy goals is therefore undesirable when the central bank can commit. Moreover, when, for example, θ_{t+1} is revealed in period t, it helps the private sector predict inflation next period more accurately, and therefore the condition identified in Proposition 1 is more likely to hold. Being secretive about its future objectives is desirable without commitment too, at least under the quadratic loss function (12).

Importantly, the precision of the private information possessed by the central bank is irrelevant for this result. This is in contrast to Moscarini (2007) who finds that, under discretion, the competence of a central bank, measured by the precision of the private signal the central bank receives about a contemporaneous shock to its objective, implies improved welfare and credibility, measured by the fineness of message space in the best equilibrium. A crucial difference is that his result is about a contemporaneous private shock, i.e. θ_t is not $\mathcal{F}_t$-measurable, while ours is about private news.

When $\{\theta_t\}_{t=0}^{\infty}$ is not $\mathcal{F}$-adapted but adapted to the central bank's filtration, then the central bank generally faces a trade-off: There are gains from making period-t actions contingent on θ_t, but that can reveal to the private sector some information about θ_t and possibly about future θ's, which is detrimental to welfare.[18] Therefore, secrecy is not in general optimal. In Appendix A.1, we provide an example in which θ is iid and the central bank possesses private information about the contemporaneous θ, and show that, when it is unable to commit, a unique Markov perfect equilibrium features full information revelation. The optimal discretionary policy in that example thus features full disclosure of private information.[19]

Stein (1989) considers a model in which there is a forward-looking constraint (in

which is necessary to show Lemma 2.

[18] This discussion holds even if the central bank only observes a noisy signal about contemporaneous θ.

[19] This is in contrast to Moscarini (2007) and Stein (1989) in which full information disclosure is never an equilibrium in a cheap-talk game. The result of Moscarini (2007) does not hold in our model because he uses a static Phillips curve in which cheap-talk can affect inflation expectation. In Appendix A.2 we discuss the model in Stein (1989) in details.

his case it's uncovered interest parity) and the central bank has private information that determines its future action. In a cheap-talk game he finds that full information revelation is desirable but impossible due to the central bank's inability to commit. This is in contrast to our result that, regardless of the central bank's ability to commit, it is desirable not to disclose any private information to the private sector. The reason for this difference is again that the private information in Stein (1989) is not a news shock. Details on this point are shown in Appendix A.2.

Waki, Dennis, and Fujiwara (2015) consider a monetary-policy delegation problem in a new Keynesian model, when the shock θ is private information to the central bank and influences the central bank's loss as in (12), and the central bank is unable to commit. Their paper differs from ours in that the central bank does not possess private news in their model (θ is iid), and their focus is on the optimal legislation to be imposed on the central bank's choice.

2.5 A three-equation new Keynesian model

So far we have considered situations in which monetary policy is chosen optimally. Now we show that the central bank may want to commit to secrecy even when it is forced to follow a suboptimal policy rule. Consider the following NK model that consists of three equations that describe the dynamic of inflation $\{\pi_t\}_{t=0}^{\infty}$, the output gap $\{x_t\}_{t=0}^{\infty}$, and the nominal interest rate $\{i_t\}_{t=0}^{\infty}$. These three equations are the dynamic IS equation:

$$x_t = \mathbb{E}_t^P[x_{t+1}] - \frac{1}{\sigma}\{i_t - \mathbb{E}_t^P[\pi_{t+1}] - r_t^n\}, \quad \forall t,$$

the new Keynesian Phillips curve (NKPC):

$$\pi_t = \kappa x_t + \beta \mathbb{E}_t^P[\pi_{t+1}] + u_t, \quad \forall t,$$

and the Taylor rule:

$$i_t = \phi_t^\pi \pi_t + \phi_t^x x_t + \eta_t, \quad \forall t,$$

where $\mathbb{E}_t^P$ denotes the private sector's conditional expectation based on information that is available to the private sector at t. We allow that the Taylor rule coefficients change stochastically, and assume that the contemporaneous shocks are known to the private sector at time t. Stochastic processes of inflation, the output gap, and the nominal interest rate constitute an equilibrium if they satisfy the above three equations.

Let $\mathcal{F}$ and $\mathcal{G}$ be two filtrations as above, and $\{\pi_t, x_t, i_t\}_{t=0}^\infty$ be an equilibrium when $\mathbb{E}_t^P[.] = \mathbb{E}[.|\mathcal{G}_t]$. Defining $\tilde{\pi}_t = \mathbb{E}[\pi_t|\mathcal{F}_t]$, $\tilde{x}_t = \mathbb{E}[x_t|\mathcal{F}_t]$, and $\tilde{i}_t = \mathbb{E}[i_t|\mathcal{F}_t]$ for all t, it is straightforward to check that $\{\tilde{\pi}_t, \tilde{x}_t, \tilde{i}_t\}_{t=0}^\infty$ is an equilibrium when $\mathbb{E}_t^P[.] = \mathbb{E}[.|\mathcal{F}_t]$. Jensen's inequality implies that

$$\mathbb{E}[L(\pi_t, x_t)] = \mathbb{E}\left[\mathbb{E}[L(\pi_t, x_t)|\mathcal{F}_t]\right] \geq \mathbb{E}\left[L(\mathbb{E}[\pi_t|\mathcal{F}_t], \mathbb{E}[x_t|\mathcal{F}_t])\right] = \mathbb{E}[L(\tilde{\pi}_t, \tilde{x}_t)].$$

Therefore, for any equilibrium when the private sector knows more than $\mathcal{F}$, there is an equilibrium under secrecy that achieves weakly lower ex-ante loss to the central bank.[20]

Bianchi and Melosi (2014) use this model with the Taylor rule which has a lagged nominal interest rate. In their model the Taylor rule coefficients change with the policy regime that switches between three regimes (one active, and two passive with different persistence). Under the no-transparency policy, the private sector is unable to distinguish two passive regimes and is unsure about the persistence of the current passive regime. Under the transparency policy, whenever the policy switches to a passive regime, the private sector is informed about the exact end date of the passive regime. This is a particular kind of communication about private news the central bank receives, and they argue that the steady-state welfare improves under transparency.

[20] Again, unless the one-period-ahead inflation forecast under $\mathcal{G}$ is the same as that under $\mathcal{F}$ almost everywhere, the ex-ante loss is strictly higher when the private sector is better informed.

Because the model in Bianchi and Melosi (2014) has a lagged nominal interest rate in the Taylor rule, we investigate numerically whether incorporating the lagged nominal rate in the monetary policy rule makes information revelation beneficial, using the three-equation model with constant coefficients: $(\phi_t^\pi, \phi_t^x) = (\phi^\pi, \phi^x)$. As shown in Section 3.4, the lagged interest rate itself does not overturn the desirability of secrecy, suggesting that the welfare improving property of transparency in Bianchi and Melosi (2014) may depend crucially on their use of the steady-state welfare. Because we are interested in whether it is beneficial for the central bank to commit to secrecy, ex-ante or time-0 expected loss is a more natural criterion.

2.6 Undesirability of information revelation without commitment

Can information revelation be beneficial when the central bank is unable to commit to a state-contingent action plan? To answer this question, we first define an equilibrium under discretion *for a given information structure.*

Definition 1 *Let $\mathcal{G} = \{\mathcal{G}_t\}_{t=0}^\infty$ be a filtration such that $\mathcal{G}_t$ for all t. A $\mathcal{G}$-adapted stochastic process $\{\pi_t, x_t\}_{t=0}^\infty$ is a $\mathcal{G}$-discretionary policy equilibrium if and only if, for all t, (π_t, x_t) solves $\min_{(\pi,x)} L(\pi, x)$ subject to $\pi = \kappa x + \beta \mathbb{E}[\pi_{t+1}|\mathcal{G}_t] + u_t$.*

Although it is conventional to focus on a Markov perfect equilibrium when considering discretionary policy, we do not require a Markov property here.

The next proposition shows that, when the loss function is quadratic, for any $\mathcal{G}$-discretionary policy equilibrium we can find an $\mathcal{F}$-discretionary policy equilibrium that achieves (weakly) lower ex-ante loss. In this sense, information revelation is undesirable even without commitment.

Proposition 3 *Suppose that L is quadratic: $L(\pi, x) = (\pi^2 + bx^2)/2$ with $b \geq 0$. Let $\mathcal{G} = \{\mathcal{G}_t\}_{t=0}^\infty$ and be a filtration such that $\mathcal{F}_t \subset \mathcal{G}_t$ for all t. Then the following holds.*

1. *For any $\mathcal{G}$-discretionary policy equilibrium $\{(\pi_t, x_t)\}_{t=0}^{\infty}$, there exists an $\mathcal{F}$-discretionary policy equilibrium $\{(\tilde{\pi}_t, \tilde{x}_t)\}_{t=0}^{\infty}$ such that*

$$\mathbb{E}[L(\pi_t, x_t)] \geq \mathbb{E}[L(\tilde{\pi}_t, \tilde{x}_t)]$$

   for all t (equality holds if and only if $\{(\pi_t, x_t)\}_{t=0}^{\infty} = \{(\tilde{\pi}_t, \tilde{x}_t)\}_{t=0}^{\infty}$ almost everywhere), and

2. *Let $\{\pi_t^*, x_t^*\}_{t=0}^{\infty}$ be the best $\mathcal{F}$-discretionary policy equilibrium, i.e. it minimizes the loss among all $\mathcal{F}$-discretionary policy equilibria. If*

$$\mathbb{E}[\pi_{t+1}^*|\mathcal{G}_t] \neq \mathbb{E}[\pi_{t+1}^*|\mathcal{F}_t]$$

   for some t with positive probability, then the best $\mathcal{G}$-discretionary policy equilibrium yields strictly larger loss minimized loss than $\{\pi_t^*, x_t^*\}_{t=0}^{\infty}$.

Proof. Let $\{(\pi_t, x_t)\}_{t=0}^{\infty}$ be a $\mathcal{G}$-discretionary policy equilibrium. Then, for all t, it satisfies the first-order necessary and sufficient condition for the problem $\min_{\pi,x} L(\pi, x)$ subject to $\pi = \kappa x + \beta\mathbb{E}[\pi_{t+1}|\mathcal{G}_t] + u_t$, which is summarized by

$$\pi_t = \frac{b/\kappa}{\kappa + b/\kappa}\{\beta\mathbb{E}[\pi_{t+1}|\mathcal{G}_t] + u_t\},$$
$$x_t = -\frac{1}{\kappa + b/\kappa}\{\beta\mathbb{E}[\pi_{t+1}|\mathcal{G}_t] + u_t\}.$$

Define $\{(\tilde{\pi}_t, \tilde{x}_t)\}_{t=0}^{\infty}$ as in Lemma 2. Then it satisfies

$$\tilde{\pi}_t = \frac{b/\kappa}{\kappa + b/\kappa}\{\beta\mathbb{E}[\tilde{\pi}_{t+1}|\mathcal{F}_t] + u_t\},$$
$$\tilde{x}_t = -\frac{1}{\kappa + b/\kappa}\{\beta\mathbb{E}[\tilde{\pi}_{t+1}|\mathcal{F}_t] + u_t\},$$

implying that $\{\tilde{\pi}_t, \tilde{x}_t\}_{t=0}^{\infty}$ is a $\mathcal{F}$-discretionary policy equilibrium. It follows from Jensen's inequality that $\mathbb{E}[L(\pi_t, x_t)] \geq \mathbb{E}[L(\tilde{\pi}_t, \tilde{x}_t)]$ for all t. Because L is quadratic, equality holds if and only if $\{(\pi_t, x_t)\}_{t=0}^{\infty} = \{(\tilde{\pi}_t, \tilde{x}_t)\}_{t=0}^{\infty}$ almost everywhere. This proves the part 1. The proof of the part 2 is the same as that of Proposition 1 and thus is omitted. ■

Note that the definition of the $\mathcal{G}$-discretionary policy equilibrium is conditional on the informational structure and does not require whether it is possible in some games with communication that the private sector is endowed with filtration $\mathcal{G}$ in an equilibrium. Nonetheless, Proposition 3 implies that, in a situation where there is a benevolent entity that can commit and impose restrictions on the central bank's actions as in Waki, Dennis, and Fujiwara (2015), it is optimal for the entity to require the central bank to utilize the public information only and ban any communication between the central bank and the private sector.

When there is no such entity, an important question is whether the best $\mathcal{F}$-discretionary policy equilibrium is indeed an equilibrium in some games with communication. If we assume that the central bank can commit to a communication strategy, then it can commit to being secretive about the private news and thus Proposition 3 implies that the answer is yes. In the present situation, however, it is natural to assume that the central bank is not able to commit to a particular information revelation strategy either, and a formal analysis requires that we set up a game with communication and characterize a set of equilibria in the game. One way to set up such a game is to introduce a cheap talk stage in which the central bank sends a message to the private sector at the beginning of each period.[21] Because in cheap-talk games there is always a "babbling" equilibrium, in which no information is transmitted, the best $\mathcal{F}$-discretionary policy equilibrium we analyzed above must also be an equilibrium in such a game with cheap talk, and therefore

[21] Fujiwara and Waki (2015b) consider a finite-period cheap-talk game in a new Keynesian model along this line.

it must remain to be the best equilibrium.[22]

3 Numerical investigation of optimal policy when the private sector becomes more informed about future shocks

Now we examine how the optimal policy changes when the private sector becomes better informed about future cost-push shocks. For this purpose, we numerically solve for the optimal policies with and without commitment, under the assumption that the private sector observes the n-period ahead cost-push shock. For simplicity we assume that cost-push shocks are iid over time, but introducing persistence does not change results qualitatively. In our notation, $\mathcal{F}$ is the filtration generated by the shock process $\{u_t\}_{t=0}^{\infty}$, and we consider for each n a situation in which the private sector is endowed with a filtration $\mathcal{G}^n$ with $\mathcal{G}_t^n = \mathcal{F}_{t+n}$ for all t. We begin with the canonical new Keynesian model, and then proceed to models with endogenous state variables, one with backward price indexation (Steinsson, 2003) and the other with endogenously accumulated capital (Edge, 2003; Takamura, Watanabe, and Kudo, 2006). Throughout we assume that the central bank is benevolent and minimizes the loss that is obtained as the second-order approximation of the representative household's utility.

3.1 Canonical new Keynesian model

The loss function is quadratic as in (3) which can be derived by the second order approximation of the welfare (see Woodford, 2003). In the new Keynesian Phillips curve in (1), $\mathbb{E}_t^P[\pi_{t+1}]$ means $\mathbb{E}[\pi_{t+1}|\mathcal{G}_t^n]$.

[22]In the babbling equilibrium, the central bank sends a message independently from its private information, and the private sector never updates its belief in response to the received message. These strategies are mutually best response.

By solving the loss minimization problem, optimal targeting rule under commitment is derived as

$$\pi_t = -\frac{1}{\varepsilon}\left(x_t - x_{t-1}\right). \tag{13}$$

Since there is no endogenous state variable, optimal targeting rule under discretion can be simply defined as

$$\pi_t = -\frac{1}{\varepsilon} x_t. \tag{14}$$

The new Keynesian Phillips curve (1) together with the targeting rule in (13) or (14) determine optimal allocations and prices. Although (13) and (14) are identical to those in the model in which the private sector does not observe future shocks, the optimal policy depends on anticipated future shocks because the new Keynesian Phillips curve does.

Throughout the numerical experiments, we use the unconditional social loss as welfare metric:[23]

$$\mathbb{L} = \text{var}\left(\pi_t\right) + \frac{\kappa}{\varepsilon}\text{var}\left(x_t\right). \tag{15}$$

Table 1: Parameter Values

Parameters	Values	Explanation
β	.99	Subjective discount factor
σ	1	Inverse of intertemporal elasticity of substitution
η	1	Inverse of Frisch elasticity
ε	6	Elasticity of substituion among differentiated products
θ	.75	Calvo parameter

Parameters are calibrated as in Table 1. Parameters σ, η, ε and θ denote the inverse of the intertemporal elasticity of substitution, the inverse of Frisch elasticity, the elasticity of substitution among differentiated products, and the Calvo parameter. $1-\theta$ is the

[23] The difference between the unconditional and the conditional losses is minuscule. This is because the discount factor is set close to unity. We thus only report the unconditional loss hereafter.

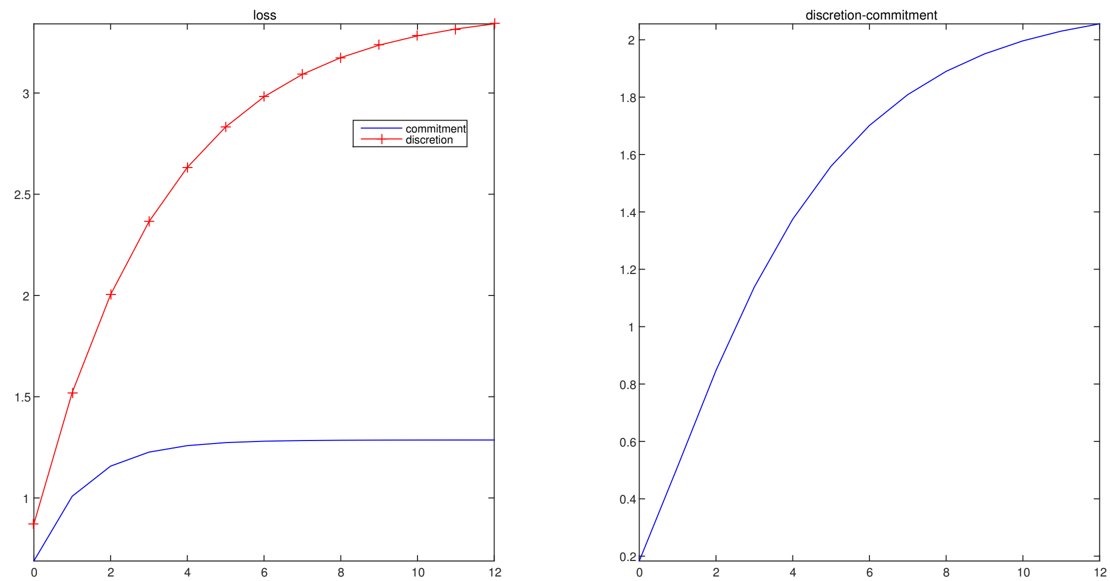

Figure 3: Loss under Commitment and Discretion

probability of re-optimization of prices. The standard deviation of the cost-push shock is set to 1%. Parameter κ is related to structural parameters as:

$$\kappa \equiv \frac{(1-\theta)(1-\beta\theta)(\sigma+\eta)}{\theta(1+\eta\varepsilon)}.$$

3.1.1 Results

Figure 1 displays how unconditional losses under commitment and under discretion change with n (shown on the horizontal axis). The case with $n = 0$ corresponds to the situation in which the private sector only observes the contemporaneous cost-push shock. The social loss is minimized at $n = 0$ under both commitment and discretion, as we have shown theoretically.

The right panel displays the difference in social loss between commitment and discretion. The relative welfare loss from discretionary monetary policy is larger when cost-push shocks in further future becomes observable by the private sector. Intuition

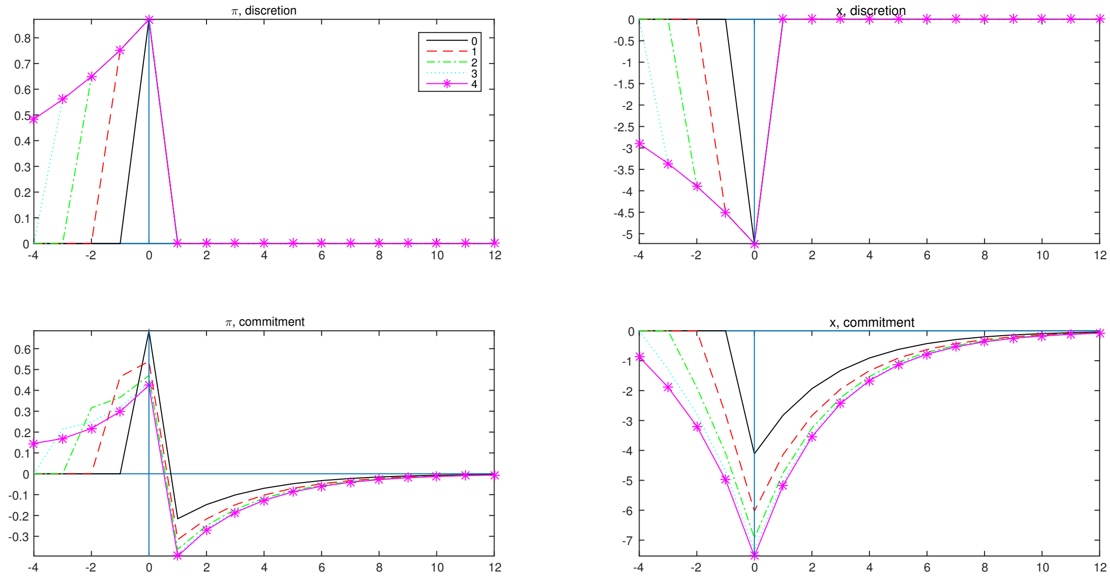

Figure 4: Impulse Responses: Commitment and Discretion

is simple. When the private sector observes more future cost-push shocks, it is desirable, from the ex-ante point of view, for the central bank to reduce the dependence of future inflation on cost-push shocks that are foreseen, because this dependence acts as a disturbance to the new Keynesian Phillips curve. Such reduction is possible when the central bank can commit, but is impossible when the central bank is unable to commit. Therefore the loss under discretion increases faster than the loss under commitment, as n increases.

Differences in responses of inflation and the output gap under commitment and under discretion can be most transparently analyzed by looking at impulse responses to an anticipated, future cost-push shock. Figure 2 draws impulse responses to the anticipated positive 1% cost-push shock. In each panel, the period when the cost-push shock materializes corresponds to 0 in x-axis. We display the responses to the news shock from $n = 0$ to 4. The top two panels depict responses of inflation and the output gap under discretion, and the bottom panels depict those under commitment.

Responses under discretion offer an intuitive explanation as to why there is no gain from revealing the private news. Observe that, irrespective of whether a shock is anticipated or not, responses after the materialization of shocks are identical. Under optimal discretionary policy, revealing future cost-push information only results in additional fluctuations before the realization of the shock, and therefore is undesirable.

In contrast, under commitment, the central bank can lower the inflation response upon materialization of a shock, which is undesirable when the private sector foresees future shocks because it disturbs the new Keynesian Phillips curve, by altering the inflation responses after the materialization and the output gap responses. It is clear in Figure 2 that the size of the inflation response in the period when the shock is realized decreases with n. As the new Keynesian Phillips curve dictates, lower contemporaneous inflation response can be achieved only by moving inflation expectation and the output gap further in the negative direction, which is inefficient.

Figure 3 clarifies this point by looking at the sum of the squared impulse responses of each variable before (left panels), upon (middle panels), and after (right panels) the materialization of the shock, respectively, as functions of n. For the output gap, they are weighted by κ/ϵ as in the loss function. The loss from the output gap response monotonically increases with n in all panels. The loss from inflation upon shock materialization decreases monotonically but the loss after materialization monotonically increases with n. The loss from inflation response before shock materialization is not monotone in n, probably because, if the news is about sufficiently distant future, the central bank can somewhat smooth its negative effects on inflation. One can observe in Figure 2 that inflation response before the materialization of a shock becomes smoother as n increases.

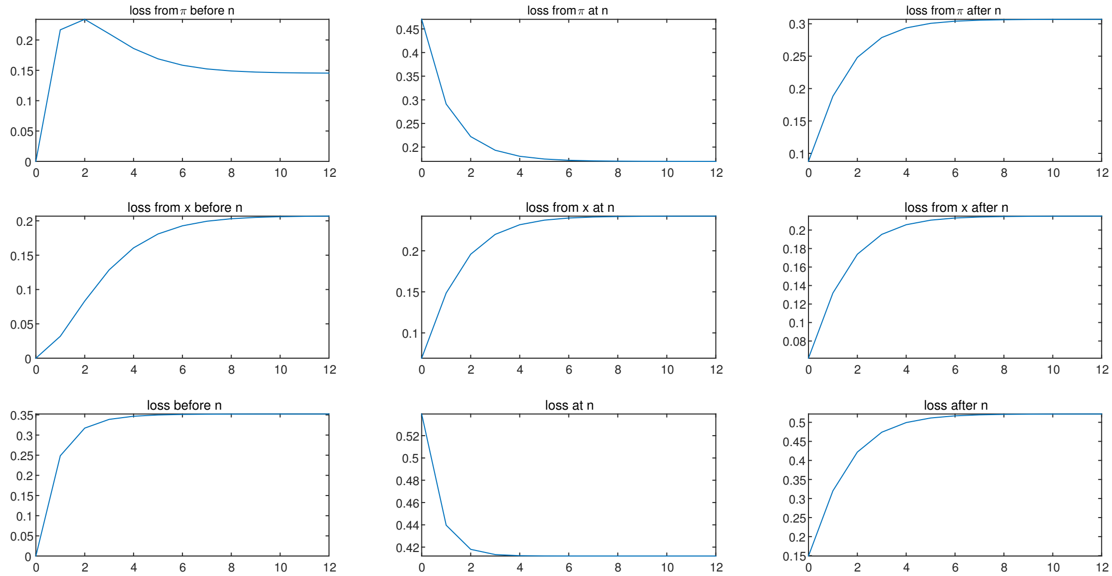

Figure 5: Loss by Timing

3.2 Indexation

Next we turn to the setting with backward price indexation, employing the analytical framework used in Steinsson (2003). In Steinsson (2003), a fraction ω of price setters are assumed to set prices P_t^B following a simple rule:

$$P_t^B = P_{t-1}^* (1 + \pi_{t-1}) \exp (x_{t-1})^{\gamma},$$

where P_{t-1}^* denotes an index of the prices set in $t-1$ and the parameter $\gamma \in [0, 1)$ controls how strong their price setting decision depends on past demand condition. Among the remaining $(1-\omega)$ fraction of price setters, the $(1-\theta)$ fraction are randomly given an opportunity to optimize their prices while the θ fraction reset their prices according to the steady-state inflation.

Steinsson (2003) derives the following linear-quadratic commitment problem: the central bank minimizes

$$\frac{1}{2}\mathbb{E}_0\sum_{t=0}^{\infty}\beta^t\left[\begin{array}{c}\pi_t^2+\frac{(1-\theta)(1-\beta\theta)(\sigma+\eta)}{\theta(1+\eta\varepsilon)\varepsilon}x_t^2\\ +\frac{\omega}{(1-\omega)\theta}\Delta\pi_t^2+\frac{(1-\theta)^2\omega\gamma^2}{(1-\omega)\theta}x_{t-1}^2-\frac{2(1-\theta)\omega\gamma}{(1-\omega)\theta}\Delta\pi_t x_{t-1}\end{array}\right],$$

subject to the hybrid new Keynesian Phillips curve:

$$\begin{aligned}\pi_t=&\frac{\beta\theta}{\omega\left(1-\theta+\beta\theta\right)+\theta}\mathbb{E}_t^P\pi_{t+1}+\frac{\omega}{\omega\left(1-\theta+\beta\theta\right)+\theta}\pi_{t-1}\\&+\frac{\left(1-\theta\right)\left(1-\omega\right)\left(1-\beta\theta\right)\left(\sigma+\eta\right)-\omega\beta\theta\gamma\left(1+\eta\varepsilon\right)}{\left[\omega\left(1-\theta+\beta\theta\right)+\theta\right]\left(1+\eta\varepsilon\right)}x_t\\&+\frac{\omega\gamma\left(1-\theta\right)}{\omega\left(1-\theta+\beta\theta\right)+\theta}x_{t-1}+u_t.\end{aligned}$$

We set $\omega=.5$ and $\gamma=.052$ as in Steinsson (2003).

3.2.1 Results

Figure 4 illustrates how the unconditional loss $\mathbb{L}^S$:

$$\begin{aligned}\mathbb{L}^S=&\operatorname{var}\left(\pi_t\right)+\frac{\left(1-\theta\right)\left(1-\beta\theta\right)\left(\sigma+\eta\right)}{\theta\left(1+\eta\varepsilon\right)\varepsilon}\operatorname{var}\left(x_t\right)+\frac{\omega}{\left(1-\omega\right)\theta}\operatorname{var}\left(\Delta\pi_t\right)\\&+\frac{\left(1-\theta\right)^2\omega\gamma^2}{\left(1-\omega\right)\theta}\operatorname{var}\left(x_{t-1}\right)-\frac{2\left(1-\theta\right)\omega\gamma}{\left(1-\omega\right)\theta}\operatorname{cov}\left(\Delta\pi_t,x_{t-1}\right),\end{aligned}\tag{16}$$

and its components weighted by parameters change with n. The unconditional loss is the smallest at $n=0$, consistent with our theoretical result. As in the canonical model, we observe that variations in inflation (and inflation difference) are reduced as n is increased from $n=2$, at the cost of higher variability in other terms, in particular, that of the output gap. Even with price indexation, “ignorance is bliss” remains to be optimal monetary policy.

Figure 5 draws the similar impulse responses to Figure 2 under indexation. Similarly

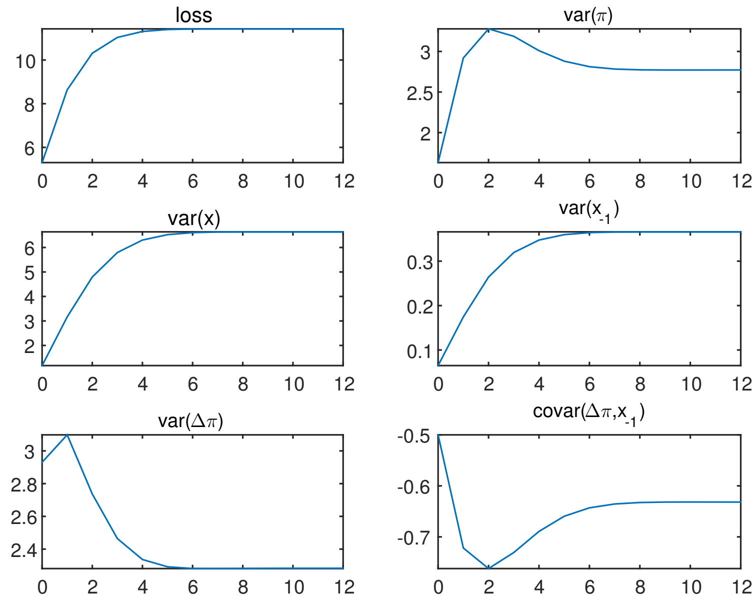

Figure 6: Terms in the Loss Function: Indexation

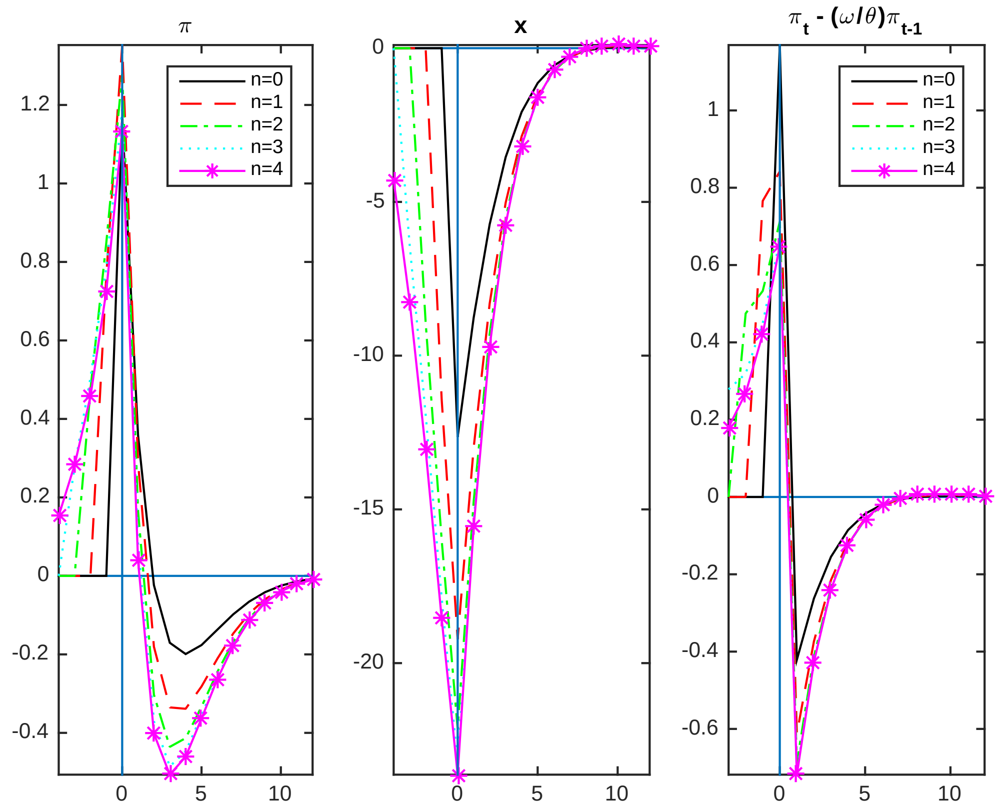

Figure 7: Impulse Responses: Indexation

to the case with the standard new Keynesian model, when the private sector observes future cost-push shocks, the central bank finds it optimal to smooth inflation rates and difference in inflation rates to reduce their negative effects on the new Keynesian Phillips curve, and this is accompanied by higher variability of the output gap. When $\gamma = 0$, this model becomes similar to the standard model with price indexation in Woodford (2003), and the quasi-difference of inflation, $\pi_t - (\omega/\theta)\pi_{t-1}$, behaves in a similar way as inflation behaves in the canonical NK model. Therefore we plot the quasi-difference of inflation in the rightmost panel in Figure 7. One can see that the impulse response presented here is qualitatively the same as that of π in the canonical model.

3.3 Endogenous Capital

In this subsection, we extend our analysis to the case with endogenous capital K_t, by employing the linear quadratic framework for optimal policy analysis by Edge (2003) and Takamura, Watanabe, and Kudo (2006) . The model is straightforward extension of the new Keynesian model to the endogenous capital formation subject to the convex capital adjustment cost:

$$\bar{I}_t = I\left(\frac{\bar{K}_{t+1}}{\bar{K}_t}\right)\bar{K}_t,$$

where $I(1) = \delta$, $I'(1) = 1$, and $I''(1) = \varepsilon_\psi$. Variables with upper bar denote level variables, while those without it are log deviations from their steady state values.

In the presence of endogenous capital, the central bank aims to minimize the quadratic loss function:

$$\frac{1}{2}\mathbb{E}_0\sum_{t=0}^{\infty}\beta^t\left[\begin{array}{l}(\sigma+\omega)Y_t^2+\sigma k^2\left[K_{t+1}-(1-\delta)K_t\right]^2\\+\varepsilon_\psi k\left(K_{t+1}-K_t\right)^2+\rho_k k\left[\beta^{-1}-(1-\delta)\right]K_t^2\\-2\sigma kY_t\left[K_{t+1}-(1-\delta)K_t\right]-2(\omega-\eta)Y_tK_t\\+\left[\theta\varepsilon\{\rho_k+(\rho_y-\omega)\eta\epsilon\}/\{\rho_k(1-\theta)(1-\beta\theta)\}\right]\pi_t^2\end{array}\right],$$

subject to the new Keynesian Phillips curve:

$$\pi_t = \beta \mathbb{E}_t^p \pi_{t+1} + \frac{(1-\theta)(1-\beta\theta)}{\theta\psi} \{(\omega+\sigma) Y_t - \sigma k K_{t+1} + [\sigma k (1-\delta) - \omega + \eta] K_t\} + u_t,$$

and the resource constraint:

$$\begin{aligned} 0 = Y_t &+ \frac{\rho_y [1-\beta(1-\delta)] - \sigma\beta(1-\delta)}{\sigma} \mathbb{E}_t^P Y_{t+1} + \frac{k\sigma(1-\delta) + \varepsilon_\psi}{\sigma} K_t \\ &- \frac{\sigma k + \varepsilon_\psi (1+\beta) + \sigma\beta k (1-\delta)^2 + \rho_k [1-\beta(1-\delta)]}{\sigma} K_{t+1} + \frac{\beta [\sigma k (1-\delta) + \varepsilon_\psi]}{\sigma} \mathbb{E}_t^P K_{t+2}, \end{aligned}$$

where Y_t denotes the output.[24]

Table 2: Parameter Values

Parameters	Values	Explanation
β	.99	Subjective discount factor
σ	1	Inverse of intertemporal elasticity of substitution
η	.11	Inverse of Frisch elasticity
ε	23/3	Elasticity of substituion among differentiated products
θ	.75	Calvo parameter
δ	.12/4	Depreciation rate
ϕ_h	4/3	Reciprocal of the elasticity of the purduction
ε_ψ	3	Capital adjustment cost parameter
ω_p	.33	Negative of the elasticity of the marginal product

Parameters are taken from Woodford (2005) and Takamura, Watanabe, and Kudo (2006). Other parameters are defined as the function of structural parameters: $\rho_y := \eta\phi_h + \omega_p \phi_h/(\phi_h - 1)$, $\rho_k := \rho_y - \eta$, $k := (1-\phi_h^{-1})/\{\beta^{-1} - (1-\delta)\}$, $\omega := \omega_\omega + \omega_p$, $\omega_\omega := \eta\phi_h$, and $\psi := 1 + \varepsilon(\rho_y - \omega)\eta/\rho_k$.

[24] We will also show impulse responses of real marginal costs MC_t and investment I_t, which are given by:

$$MC_t = (\omega+\sigma) Y_t - \sigma k K_t + [\sigma k (1-\delta) - \omega + \eta] K_{t-1},$$

and

$$I_t = k [K_{t+1} - (1-\delta) K_t].$$

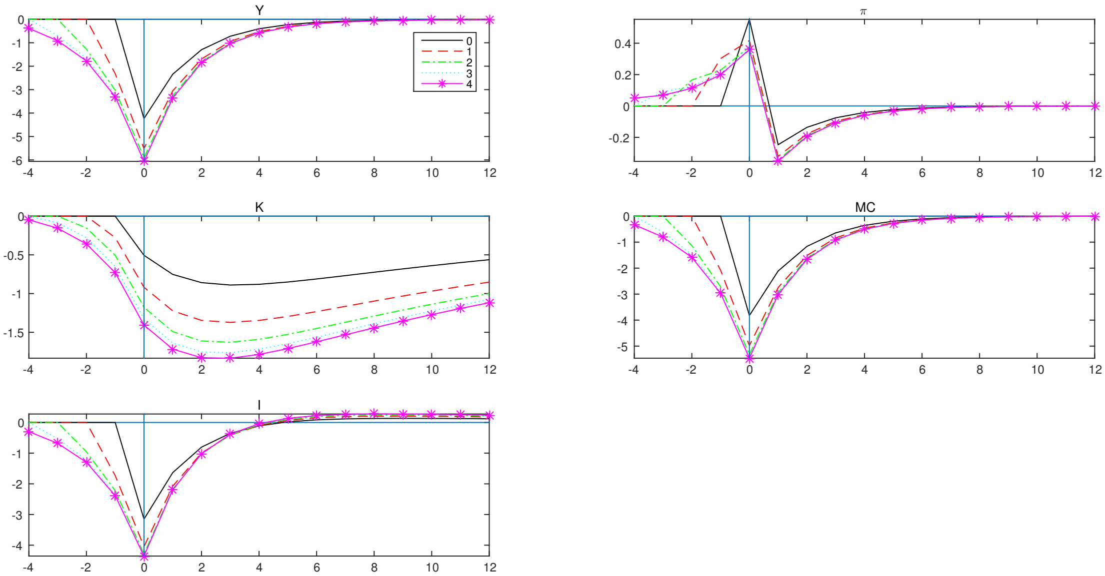

Figure 8: Impulse Responses: Endogenous Capital

3.3.1 Results

Figure 6 compares the impulse responses for different n's. Responses of inflation and marginal costs are qualitatively similar to the above two cases, noting that the marginal cost is proportional to the output gap in the canonical model and the model with price indexation. The response of marginal costs is magnified as n increases, and the inflation response upon realization of a shock is reduced. However, notice that it takes much longer for the impulse response of the marginal cost to come close to zero. This is due to the fact that the marginal costs depend on capital that adjusts only slowly over time. The top-left panel shows that it takes long for capital to come back to the steady-state level even if n is low, and that the response of capital increases as n increases. This slow-moving property of the marginal costs keeps inflation response away from zero, before and after the realization of a shock.

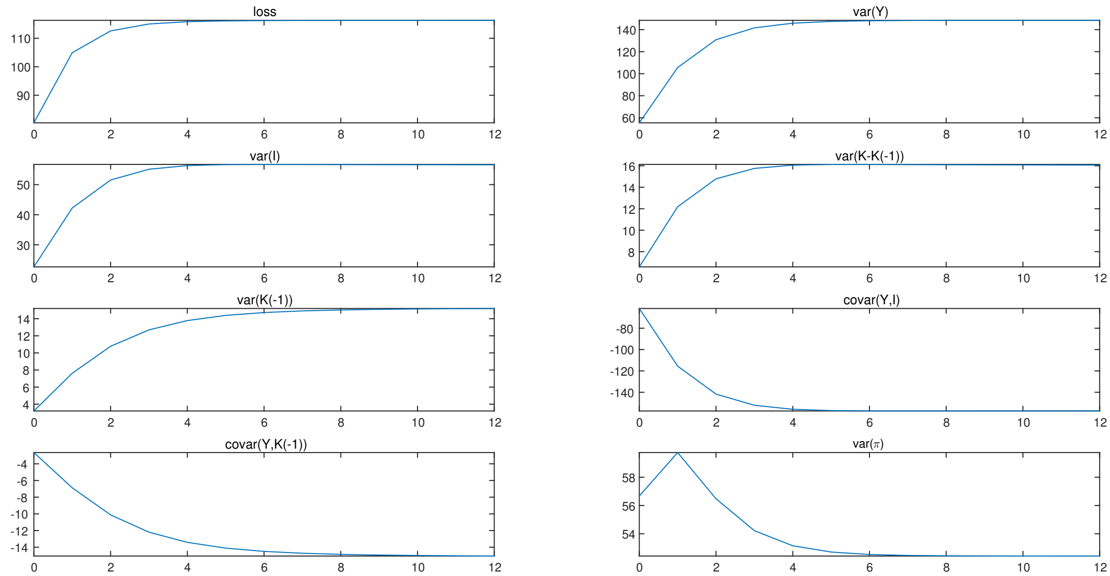

Figure 9: Terms in the Loss Function: Endogenous Capital

Figure 7 compares the unconditional loss $\mathbb{L}^K$:

$$\mathbb{L}^K = (\sigma + \omega)\,\text{var}\,(Y_t) + \sigma k^2 \text{var}\,(I_t) + \varepsilon_\psi k \text{var}\,(\Delta K_t) + \rho_k k \left[\beta^{-1} - (1-\delta)\right] \text{var}\,(K_t)$$
$$- 2\sigma^{-1} k \text{cov}\,(Y_t, I_t) - 2\,(\omega - \eta)\,\text{cov}\,(Y_t, K_t) + \frac{\theta\varepsilon\left[\rho_k + (\rho_y - \omega)\,\eta\varepsilon\right]}{\rho_k\,(1-\theta)\,(1-\beta\theta)} \text{var}\,(\pi_t)\,. \qquad (17)$$

and each of its components weighted by parameters for different values of n. Again the unconditional loss is increasing in n, which is consistent with our theoretical results. Results are similar to those obtained from the standard new Keynesian model and that with price indexation as examined above. Again, there exists the expected virtue of ignorance.

3.4 A three-equation model with a lagged interest rate

Because Bianchi and Melosi (2014) find steady-state welfare gains from transparency using the Taylor rule with a lagged nominal interest rate, now we incorporate the lagged

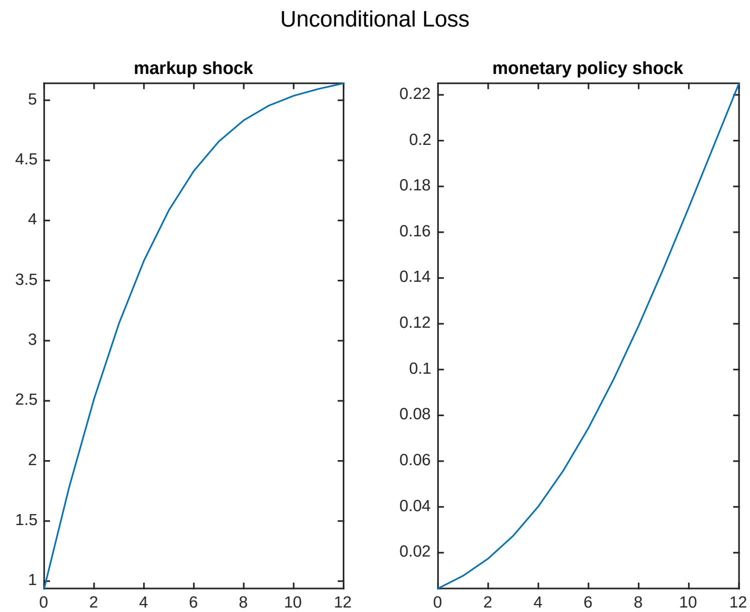

Figure 10: Welfare loss vs. n in the three equation model with a lagged interest rate

policy rate to the Taylor rule in a three equation model to examine its welfare consequences. The Taylor rule is now

$$i_t = \rho i_{t-1} + (1-\rho)(\phi_\pi \pi_t + \phi_x x_t) + \eta_t, \quad 0 < \rho < 1.$$

Structural parameters are the same as in Table 1 and we use $(\rho, \phi_\pi, \phi_x) = (0.6, 1.6, 0.3)$.

Figure 10 reports how the ex-ante loss varies with n, for the mark-up shock case and for the monetary shock case. In both cases, welfare loss is increasing in n, and therefore revealing information about future shocks is detrimental to welfare. This pattern does not change with ρ, and higher values for ρ (e.g. $\rho = 0.9$) produce the same pattern. Although the model considered here is not identical to Bianchi and Melosi (2014), the above result suggests that the lagged nominal interest rate in the Taylor rule by itself does not have significant implications on the welfare consequences of information revelation.

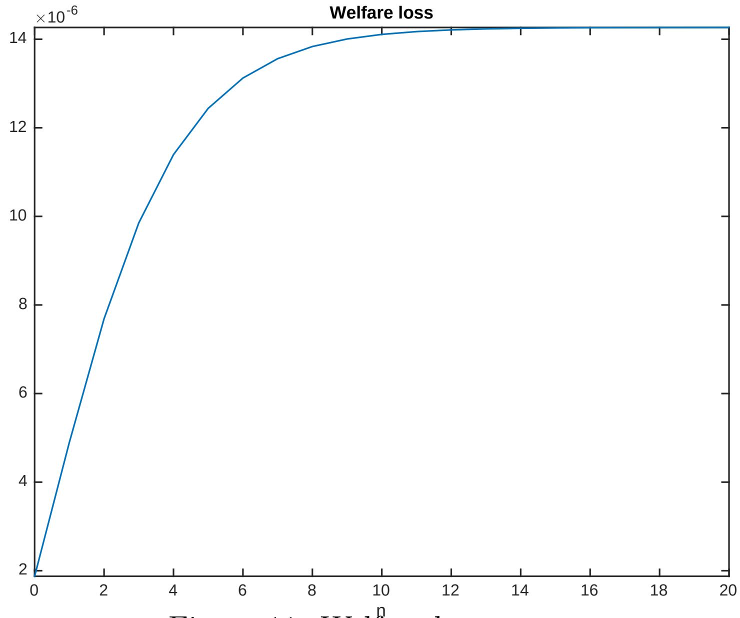

Figure 11: Welfare loss vs. n

3.5 A nonlinear canonical model

As a last exercise we consider a nonlinear canonical Calvo model and solve for the Ramsey policy using the Dynare command `ramsey_policy`, which computes the policy function based on the first-order approximation of the first-order conditions for a fully nonlinear Ramsey problem and the planner's maximized objective based on the second-order approximation of the Lagrangian. A complete description of the model is provided in Appendix A.4.

Figure 11 displays how the representative household's utility changes with n. We plot the maximized utility of the representative household in the deterministic economy (invariant to n) minus that in the stochastic economy for each n. Clearly the figure shows that the welfare loss increases in n.[25]

In Appendix (available upon request), we show that our main results hold in a nonlinear Rotemberg model with quadratic adjustment costs.

[25] We need to make some adjustment to `oo_.planner_objective_value`, one of the output of Dynare's `ramsey_policy` command. In Appendix A.4 we explain how and why we do so.

4 Conclusion

How should monetary policy be designed when the central bank has private information about future economic conditions? We show that when the central bank has a dual-mandate-type objective function it finds it undesirable to disclose private news to help the private sector form more accurate forecast about the future. Being secretive about private news, or i.e. "ignorance is bliss", constitutes optimal monetary policy when the central bank receives such information. This result also casts doubt on the usefulness of the *Delphic* forward guidance, if it is based on private news about future shocks. Our result also implies that, in a wide class of new Keynesian models, if information acquisition is costly for the central bank, it won't have incentives to collect information to forecast the future better than the private sector.

We have identified a class of new Keynesian models in which the information revelation is only harmful to the central bank. There are mechanisms that are absent in the models in this paper but are likely to counteract the negative effects of information revelation. For example, when the representative household is not an expected utility maximizer but instead has a preference for early resolution of uncertainty, then there can be a direct, positive effect on social welfare from revealing information regarding future shocks to the household. If the price setters receive idiosyncratic, noisy private signals regarding future shocks, then the resulting price distribution can be more dispersed than it would be when they have homogeneous information. Providing a public signal may improve welfare because it may reduce the price dispersion through a reduction in inflation expectation dispersion, which is the source of inefficiency in the canonical new Keynesian model. It would be interesting to examine whether these mechanisms can more than offset the mechanism identified in the present paper, for a set of reasonable parameter values. It is also interesting to investigate whether the Delphic forward guidance can be useful for the conduct of fiscal policy (Fujiwara and Waki, 2015a). They are left for our future research.

References

Adam, K., and R. M. Billi (2006): "Optimal Monetary Policy under Commitment with a Zero Bound on Nominal Interest Rates," *Journal of Money, Credit and Banking*, 38(7), 1877–1905.

Angeletos, G.-M., and A. Pavan (2007): "Efficient Use of Information and Social Value of Information," *Econometrica*, 75(4), 1103–1142.

Athey, S., A. Atkeson, and P. J. Kehoe (2005): "The Optimal Degree of Discretion in Monetary Policy," *Econometrica*, 73(5), 1431–1475.

Beaudry, P., and F. Portier (2006): "Stock Prices, News, and Economic Fluctuations," *American Economic Review*, 96(4), 1293–1307.

——— (2014): "News-Driven Business Cycles: Insights and Challenges," *Journal of Economic Literature*, 52(4), 993–1074.

Bianchi, F., and L. Melosi (2014): "Constrained Discretion and Central Bank Transparency," *unpublished manuscript.*

Campbell, J. R., C. L. Evans, J. D. Fisher, and A. Justiniano (2012): "Macroeconomic Effects of Federal Reserve Forward Guidance," *Brookings Papers on Economic Activity*, 44(1 (Spring), 1–80.

Christiano, L., C. Ilut, R. Motto, and M. Rostagno (2010): "Monetary policy and stock market booms," *Proceedings - Economic Policy Symposium - Jackson Hole*, pp. 85–145.

Crawford, V. P., and J. Sobel (1982): "Strategic Information Transmission," *Econometrica*, 50(6), 1431–51.

Cukierman, A., and A. H. Meltzer (1986): "A Theory of Ambiguity, Credibility, and Inflation under Discretion and Asymmetric Information," *Econometrica*, 54(5), 1099–1128.

Edge, R. M. (2003): "A Utility-Based Welfare Criterion in a Model with Endogenous Capital Accumulation," Finance and Economics Discussion Series 2003-66, Board of Governors of the Federal Reserve System (U.S.).

Eggertsson, G. B., and M. Woodford (2003): "The Zero Bound on Interest Rates and Optimal Monetary Policy," *Brookings Papers on Economic Activity*, 34(2003-1), 139–235.

Fujiwara, I. (2005): "Is the Central Bank's Publication of Economic Forecasts Influential?," *Economics Letters*, 89(3), 255–261.

Fujiwara, I., Y. Hirose, and M. Shintani (2011): "Can News Be a Major Source of Aggregate Fluctuations? A Bayesian DSGE Approach," *Journal of Money, Credit and Banking*, 43(1), 1–29.

Fujiwara, I., and Y. Waki (2015a): "Is forward guidance useful for fiscal policy?," *unpublished manuscript*.

——— (2015b): "Private News and Monetary Policy: A Simple Analytical Investigation," *unpublished manuscript*.

Gaballo, G. (2013): "Rational Inattention to News: The Perils of Forward Guidance," Working papers 416, Banque de France.

Galí, J. (2008): *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework*. Princeton University Press, Princeton.

Hellwig, C. (2005): "Heterogeneous information and the welfare effects of public information disclosures," Discussion paper, UCLA.

Jaimovich, N., and S. Rebelo (2009): "Can News about the Future Drive the Business Cycle?," *American Economic Review*, 99(4), 1097–1118.

Lorenzoni, G. (2010): "Optimal Monetary Policy with Uncertain Fundamentals and Dispersed Information," *Review of Economic Studies*, 77(1), 305–338.

Morris, S., and H. S. Shin (2002): "Social Value of Public Information," *American Economic Review*, 92(5), 1521–1534.

Moscarini, G. (2007): "Competence Implies Credibility," *American Economic Review*, 97(1), 37–63.

Romer, D. H., and C. D. Romer (2000): "Federal Reserve Information and the Behavior of Interest Rates," *American Economic Review*, 90(3), 429–457.

Schmitt-Grohé, S., and M. Uribe (2012): "What's News in Business Cycles," *Econometrica*, 80(6), 2733–2764.

Stein, J. C. (1989): "Cheap Talk and the Fed: A Theory of Imprecise Policy Announcements," *American Economic Review*, 79(1), 32–42.

Steinsson, J. (2003): "Optimal Monetary Policy in an Economy with Inflation Persistence," *Journal of Monetary Economics*, 50(7), 1425–1456.

Svensson, L. E. (2014): "Forward Guidance," NBER Working Papers 20796, National Bureau of Economic Research, Inc.

Svensson, L. E. O. (2006): "Social Value of Public Information: Comment: Morris and Shin (2002) Is Actually Pro-Transparency, Not Con," *American Economic Review*, 96(1), 448 – 452.

Takamura, T., T. Watanabe, and T. Kudo (2006): "Optimal Monetary Policy at the Zero Interest Rate Bound: The Case of Endogenous Capital Formation," Discussion paper, Research Center for Price Dynamics, Institute of Economic Research, Hitotsubashi University.

Waki, Y., R. Dennis, and I. Fujiwara (2015): "The Optimal Degree of Monetary-Discretion in a New Keynesian Model with Private Information," Discussion papers 15007, Research Institute of Economy, Trade and Industry (RIETI).

Walsh, C. E. (2010): *Monetary Theory and Policy*. The MIT Press, Cambridge, 3 edn.

Woodford, M. (2003): *Interest and Prices: Foundations of a Theory of Monetary Policy*. Princeton University Press, Princeton.

——— (2005): "Firm-Specific Capital and the New Keynesian Phillips Curve," *International Journal of Central Banking*, 1(2), 1–46.

A Appendix

A.1 Private information about contemporaneous shock to the policy objective

Here we provide an example in which the central bank possesses private information about *contemporaneous* θ and the optimal policy does not feature secrecy. For simplicity, we abstract from other shocks, from news shocks, and from imperfect knowledge of the central bank, and assume that the central bank perfectly observes only θ_t in period t while the private sector is completely uninformed, i.e. it observes neither θ itself nor some noisy signals. We further assume that θ_t is iid with mean zero, that the central bank is unable to commit, and that the loss function is given by (12). We focus on a Markov perfect equilibrium in which the central bank uses a time-invariant strategy that depends only on the current realization of θ.

Let (π^*, x^*, π^{e*}) with $(\pi^*, x^*) : \Theta \to \mathbb{R}^2$ and $\pi^{e*} \in \mathbb{R}$ be a Markov perfect equilibrium. A simple observation is that the private sector's inflation expectation is unaffected even if the central bank reveals some information about contemporaneous θ. The central bank's strategy $(\pi^*, x^*) : \Theta \to \mathbb{R}^2$ must solve

$$\min_{(\pi,x)} \frac{1}{2}\mathbb{E}_\theta[(\pi(\theta) - \theta)^2 + bx(\theta)^2]$$

subject to

$$\pi(\theta) = \kappa x(\theta) + \beta\pi^{e*}, \quad \forall\theta.$$

This implies, for all θ,

$$x^*(\theta) = -\frac{1}{\kappa + b/\kappa}(\theta - \beta\pi^{e*}),$$
$$\pi^*(\theta) = \frac{b/\kappa}{\kappa + b/\kappa}\beta\pi^{e*} + \frac{\kappa}{\kappa + b/\kappa}\theta.$$

Rational expectation implies $\pi^{e*} = 0$, and thus

$$(x^*(\theta), \pi^*(\theta)) = \left(-\frac{1}{\kappa + b/\kappa}\theta, \frac{\kappa}{\kappa + b/\kappa}\theta \right).$$

This shows that the optimal discretionary policy exploits the central bank's private information.

A.2 Comparison to Stein (1989) – Role of private news

Here we demonstrate that the reason for this difference is that the private information in Stein (1989) is not a news shock, by rewriting his model as a two-period new Keynesian model. The central bank's loss function is

$$\mathbb{E}[(\pi_0 - \theta)^2 + (\pi_1(\theta) - \theta)^2 + \pi_1(\theta)^2].$$

Central bank is unable to commit and chooses π_1 as a function of θ, implying the best response of

$$\pi_1(\theta) = \theta/2.$$

θ is private information to the central bank, and has mean 0 and variance σ_θ^2. The inflation rate in period 0 is determined by the new Keynesian Phillips curve:

$$\pi_0 = \mathbb{E}^P[\pi_1(\theta)].$$

This setting is neither identical to nor nested by our setting.

It is then straightforward to calculate the losses under full and no information revelation. Full revelation implies $\pi_0 = \pi_1(\theta)$, and the loss is $(3/4)\sigma_\theta^2$. No revelation implies $\pi_0 = 0$, and the loss is $(3/2)\sigma_\theta^2$, which is bigger than the loss under full-revelation.

Desirability of full revelation in Stein's model is due to the assumption that θ is constant over time, i.e., θ is not purely a news shock. Because of this property, it is desirable if π_0 varies positively with θ, which is achieved when full information is revealed. Without this property, we can easily show that no revelation is better than full revelation. Consider an alternative loss function where θ only affects the period 1 loss.

$$\mathbb{E}[\pi_0^2 + (\pi_1(\theta) - \theta)^2 + \pi_1(\theta)^2].$$

Then no revelation results in the loss of $(1/2)\sigma_\theta^2$ while full revelation results in the loss of $(3/2)\sigma_\theta^2$.

The undesirability of information revelation also holds true if the loss function is hit by two shocks that are independent over time, as

$$\mathbb{E}[(\pi_0 - \theta_0)^2 + (\pi_1(\theta_1) - \theta_1)^2 + \pi_1(\theta_1)^2].$$

Unlike the example in A.2, revealing θ_0 is irrelevant for welfare. This is because inflation in period 0 is pinned down by $\pi_0 = \mathbb{E}^P[\theta_1/2]$ and thus is independent of θ_0. If we change the minimization problem to

$$\min \mathbb{E}[(\pi_0 - \theta_0)^2 + x_0^2 + (\pi_1(\theta_1) - \theta_1)^2 + \pi_1(\theta_1)^2]$$

subject to $\pi_1(\theta) = \theta/2$ and

$$\pi_0 = x_0 + \mathbb{E}^P[\pi_1(\theta)],$$

then under the assumption that the central bank does not observe θ_1, we see that the optimal choice of (π_0, x_0) depends on (and only on) θ_0.

A.3 The $\mathcal{F}$-adaptedness constraint in the optimal secretive commitment problem

In the minimization problem that defines the optimal secretive commitment policy, the central bank is required to choose an $\mathcal{F}$-adapted process. However, this is not a binding constraint. Consider the following *relaxed* problem:

$$\min_{\{(\pi_t,x_t)\}_{t=0}^{\infty}} \mathbb{E}[\sum_{t=0}^{\infty} \delta^t L(\pi_t, x_t)] \tag{18}$$

subject to (5) and the constraint that the process $\{(\pi_t, x_t)\}_{t=0}^{\infty}$ is adapted to $\mathcal{G}$ with $\mathcal{F} \subset \mathcal{G}$.

Let $\{(\pi_t, x_t)\}_{t=0}^{\infty}$ be a solution to the above problem. Define $\{(\tilde{\pi}_t, \tilde{x}_t)\}_{t=0}^{\infty}$ by

$$(\tilde{\pi}_t, \tilde{x}_t) = (\mathbb{E}[\pi_t|\mathcal{F}_t], \mathbb{E}[x_t|\mathcal{F}_t])$$

for all t. Then $\{(\tilde{\pi}_t, \tilde{x}_t)\}_{t=0}^{\infty}$ is $\mathcal{F}$-adapted, and is in the constraint set in the above problem. Moreover, Jensen's inequality implies

$$\mathbb{E}[L(\pi_t, x_t)] = \mathbb{E}\left[\mathbb{E}[L(\pi_t, x_t)|\mathcal{F}_t]\right] \geq \mathbb{E}[L(\tilde{\pi}_t, \tilde{x}_t)].$$

Therefore $\{(\tilde{\pi}_t, \tilde{x}_t)\}_{t=0}^{\infty}$ must be a solution to the above problem too.

Importantly, $\{(\tilde{\pi}_t, \tilde{x}_t)\}_{t=0}^{\infty}$ is in the constraint set of the problem that defines the optimal secretive commitment policy. Because $\{(\tilde{\pi}_t, \tilde{x}_t)\}_{t=0}^{\infty}$ solves the above relaxed problem, it must also be the optimal secretive commitment policy. In other words, when the private sector's filtration is fixed at $\mathcal{F}$, the central bank does not benefit from utilizing its private information.

A.4 Ramsey policy in a nonlinear Calvo model

A.4.1 The nonlinear model used in Section 3.5

A Ramsey policy in a nonlinear Calvo model maximizes social welfare:

$$\mathbb{E}\sum_{t=0}^{\infty}\beta^{t}\left[\frac{C_t^{1-\sigma}}{1-\sigma}-\chi\frac{N_t^{1+\eta}}{1+\eta}\right],$$

subject to the nonlinear equilibrium conditions:

$$\begin{aligned}
C_t^{-\sigma} &= \beta\frac{1+i_t}{1+\pi_{t+1}}C_{t+1}^{-\sigma},\\
K_t &= \left[\frac{1-\theta\left(1+\pi_t\right)^{\varepsilon-1}}{1-\theta}\right]^{\frac{1}{1-\varepsilon}}F_t,\\
F_t &= 1+\theta\beta\mathbb{E}_t\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\frac{Y_{t+1}}{Y_t}\left(1+\pi_{t+1}\right)^{\varepsilon}F_{t+1},\\
K_t &= \exp\left(\mu_t\right)\frac{\chi N_t^{\eta}}{C_t^{-\sigma}}+\theta\beta\mathbb{E}_t\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\frac{Y_{t+1}}{Y_t}\left(1+\pi_{t+1}\right)^{1+\varepsilon}K_{t+1},\\
Y_t &= \frac{N_t}{\Delta_t},\\
\Delta_t &= \left(1-\theta\right)\left(\frac{1-\theta\pi_t^{\varepsilon-1}}{1-\theta}\right)^{\frac{\varepsilon}{\varepsilon-1}}+\theta\pi_t^{\varepsilon}\Delta_{t-1}.
\end{aligned}$$

C_t and N_t denote aggregate consumption and labor imput, respectively. Δ_t is the price dispersion term defined as

$$\Delta_t := \int_0^1\left[\frac{p_t\left(j\right)}{P_t}\right]^{-\theta}\mathrm{d}j,$$

where P_t and $p_t\left(j\right)$ denotes the consumer price index and the price set by firm j, respectively. μ_t represents a mark-up shock and is related to the cost-push shock as follows:[26]

$$u_t := \frac{\kappa}{\sigma+\eta}\mu_t.$$

[26] In Section 3.1, the model is solved under the firm-specific labor market, while it is not assumed in this nonnlinear model. Results here do not change even under the firm-specific labor market.

Parameter values are consistent with Table 1: $\sigma = 1$, $\beta = 0.99$, $\theta = 0.75$, $\epsilon = 6$, $\chi = 1$, and $\eta = 1$.

A.4.2 Welfare adjustment

When using Dynare, we model an n-period-ahead news shock as a shock that realizes at time t but enters the system only at time $t+n$. If we denote the shock by u, then in the Dynare `mod` file, the system includes `u(-n)`, which means the shock u affects the system with n lags. For each n, we use the command `ramsey_policy` to solve for the optimal commitment policy and to obtain the maximized planner's objective.

Although the command `ramsey_policy` computes the maximized value of the planner's objective and stores it in `oo_.planner_objective_value`, we cannot compare this value across different n's. The reason is simple yet subtle: Dynare sets shocks that realize before time 0 to zero. Therefore for example when $n = 10$, no shock hits the system between time 0 and 9, while when $n = 0$ shocks are non-zero from time 0. The value stored in `oo_.planner_objective_value` includes direct gains from being free from shocks until time $n - 1$, which increase with n.

For this reason, when comparing $n = 0, 1, ..., N$, we compute the representative household's utility for n by assuming that

1. Between time 0 to $N-n-1$ the economy is in the steady state (which is independent of n), and
2. The utility from time $N - n$ is the value stored in `oo_.planner_objective_value` (therefore the value is discounted by β^{N-n}).

Figure 11 reports numbers after the adjustment. Without the adjustment, the maximized planner's objective can increase with n when n is sufficiently large. Indeed, we even find cases in which the values in `oo_.planner_objective_value` increases with n for large n when we solve the LQ model with `ramsey_policy`.