Private News and Monetary Policy

Forward Guidance or (The Expected Virtue of Ignorance)*

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Abstract

How should monetary policy be designed when the central bank has private information about future economic conditions? When private news about shocks to future fundamentals is added to an otherwise standard new Keynesian model, social welfare deteriorates by the central bank's reaction to or revelation of such news. 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. 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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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 side 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, regardless of the central bank's ability to commit, it is detrimental to social welfare if the private sector becomes better informed about future economic conditions. In other words, there exists the *expected virtue of ignorance*. Therefore, the benevolent central bank finds it optimal to be completely secretive about its private news, 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 loss function, but do not assume specific forms of information revelation from the central bank.[2] 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 expectation becomes more dispersed. This increased dispersion in inflation expectation acts as an additional source of disturbance in the new Keynesian Phillips curve, and therefore it reduces social welfare.

Our result of the optimality of "ignorance is bliss" remains true 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. 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 should be secretive even if it receives 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

[2] Precisely speaking, we assume that the loss function is quadratic for the case without the central bank's commitment ability.

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. 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). Inclusion of endogenous state variables in the model does not alter these results.

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.[3] 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 are heterogeneously informed about contemporaneous economic conditions, and mainly on static settings.[4] 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

[3] 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.

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

information among private agents nor a need for coordinating their actions in our model, but information revelation is still detrimental to welfare.

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.

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 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 a prototypical new Keynesian model.[5]

[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.

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 ask this question: is it socially desirable to make the private sector better-informed about future cost-push shocks? We find that the answer to this questions is no, regardless of the way the central bank reveals information to the private sector, and regardless of the central bank's commitment ability. Moreover, optimal monetary policy never exploits superior information the central bank possesses. This 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.

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 (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.

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

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 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]

Social loss is given by

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

where L be a strictly convex, momentary loss function and $\beta \in [0, 1)$ is the discount factor. A common specification for L is a quadratic function:

$$L(\pi, x) = \frac{1}{2}\left(\pi^2 + bx^2\right), \quad b \geq 0. \tag{3}$$

For now we assume that the only fundamental shock that hits the economy is the cost-push shock, $\{u_t\}_{t=0}^{\infty}$. Its precise nature does not affect our theoretical results, and thus we do not impose any particular structure.[8] 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

[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.

[8] 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.

$\{u_t\}_{t=0}^{\infty}$ is adapted to it.[9] This allows that the private sector also observes informative signals about future cost-push shocks. There is a central bank, and it is endowed with a filtration that is finer than $\mathcal{F}$. The central bank has thus more information about future cost-push shocks than does the private sector.

2.2 An illustrative, two-period model

We first provide a simple explanation for why revealing an anticipated shock is not socially desirable in a simple analytical framework and then a formal proof for this undesirability of information revelation in more general setting.

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 ex-ante social loss is quadratic as in (3) with $b = 0$:

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

where, for simplicity of analysis, we assume that $\beta = 1$.[10] The new Keynesian Phillips curve is given by

$$\begin{aligned} \pi_0 &= \mathbb{E}^P \pi_1 + u_0, \\ \pi_1 &= u_1. \end{aligned}$$

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. Because the period-1 inflation is solely

[9] This is not crucial. If $\{u_t\}_{t=0}^{\infty}$ is not $\mathcal{F}$-adapted, replace u_t in the new Keynesian Phillips curve with $\mathbb{E}[u_t|\mathcal{F}_t]$ and our results hold.

[10] Our assumption of $b = 0$ is not crucial because, if $b > 0$, the central bank finds it optimal to set the output gap to zero as long as $\kappa = 0$.

determined by the period-1 shock, the central bank's ability to commit is irrelevant.

When information about the future fundamental shock is not revealed, 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 is thus

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

If the private sector becomes informed about u_1, then $\mathbb{E}^P \pi_1 = u_1$ and the new Keynesian Phillips curve implies $\pi_0 = u_0 + u_1$. The ex-ante welfare loss is now given by

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

This simple example clarifies why the perfect revelation of future cost-push shocks is detrimental to welfare. Revelation of the future shock only increases the volatility of inflation expectation and, therefore, that of inflation in period 0. Thus, no revelation of future cost-push shock is better than full revelation. This implication holds true even if κ and b are strictly positive and the central bank can choose the output gap in periods 0 and 1.

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

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

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 $\{\mathcal{F}_t\}_{t=0}^{\infty}$.

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 some information revelation from the central bank is socially beneficial. 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 information is revealed 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 social loss from the loss achieved by the optimal secretive policy. We also show that, when the private sector's information is improved in a way that its inflation forecast becomes better, social loss is strictly increased.

The following lemma shows that the presence of a better informed private sector does not reduce social loss.

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

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

for any convex function V*. When* V *is strictly convex, 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 $\mathcal{H}$ 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

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

for all t, and it follows that, when V 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. ■

In Lemma 2 we allow for the possibility that $\{(\pi_t, x_t)\}_{t=0}^{\infty}$ is adapted to a strictly finer filtration than the private sector's. This happens, e.g., when the central bank takes an action, using its private information, that directly affects either π or x, but the private sector's inference is imperfect.

Lemma 2 shows that endowing the private sector with larger filtration is never strictly better, in terms of the loss. 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 social loss under information revelation is strictly higher than that of the optimal secretive commitment policy.

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

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

then the loss from $\{(\pi^*_t, x^*_t)\}_{t=0}^{\infty}$ is strictly smaller than that from any $\mathcal{H}$-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 $\mathcal{H}$-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

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

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

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

■

Simple intuition is obtained by rewriting (6) as

$$\pi_t = \kappa x_t + \beta \mathbb{E}[\pi_{t+1}|\mathcal{F}_t] + u_t + \beta\{\mathbb{E}[\pi_{t+1}|\mathcal{G}_t] - \mathbb{E}[\pi_{t+1}|\mathcal{F}_t]\}. \tag{9}$$

Because cost-push shocks are F-adapted, the last term in the right hand side is orthogonal to u_t, and its expected value conditional on $\mathcal{F}_t$ is zero. Therefore, if the last term is non-zero, it is essentially the same as having another disturbance term in the new Keynesian Phillips curve that is orthogonal to the cost-push shock, which is undesirable.

The condition identified 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

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

as the left hand side depends on u_{t+1} but the right hand side does not.[11]

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

[11] 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.

help predicting the future inflation (under the optimal secretive commitment policy) any better.

2.4 Undesirability of information revelation without commitment

Can information revelation be beneficial when the central bank is unable to commit? To answer this question, we first define an equilibrium under discretion.

Definition 1 *Let $\mathcal{G} = \{\mathcal{G}_t\}_{t=0}^{\infty}$ and $\mathcal{H} = \{\mathcal{H}_t\}_{t=0}^{\infty}$ be filtrations such that $\mathcal{G}_t \subset \mathcal{H}_t$ for all t. A $\mathcal{H}$-adapted stochastic process $\{\pi_t, x_t\}_{t=0}^{\infty}$ is a $(\mathcal{G}, \mathcal{H})$-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.[12]

The next proposition shows that, at least when the loss function is quadratic, information revelation is undesirable even without commitment.

Proposition 2 *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 $\mathcal{H} = \{\mathcal{H}_t\}_{t=0}^{\infty}$ be filtrations such that $\mathcal{F}_t \subset \mathcal{G}_t \subset \mathcal{H}_t$ for all t. Then the following holds.*

1. *For any $(\mathcal{G}, \mathcal{H})$-discretionary policy equilibrium $\{(\pi_t, x_t)\}_{t=0}^{\infty}$, there exists a $(\mathcal{F}, \mathcal{F})$-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

[12] A $(\mathcal{G}, \mathcal{H})$-discretionary policy equilibrium is $\mathcal{G}$-measurable when L is strictly convex.

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

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

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

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

implying that $\{\tilde{\pi}_t, \tilde{x}_t\}_{t=0}^\infty$ is a $(\mathcal{F}, \mathcal{F})$-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 essentially the same as that of Proposition 1 and thus is omitted. ∎

2.5 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.

2.5.1 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 version of the model in Eggertsson and Woodford (2003), 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 3 *Let $\mathcal{G} = \{\mathcal{G}_t\}_{t=0}^{\infty}$ and $\mathcal{H} = \{\mathcal{H}_t\}_{t=0}^{\infty}$ be filtrations such that $\mathcal{F}_t \subset \mathcal{G}_t \subset \mathcal{H}_t$ 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 $\mathcal{H}$-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 social loss is lowered, but at the same time that inflation expectation is reduced and the social 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.

2.5.2 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 social loss. Let $\{\theta_t\}_{t=0}^{\infty}$ be an exogenous stochastic process, and the social loss is now given by

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

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.[13] This assumption is useful to isolate the effects of revealing private news about future

[13] Otherwise we are unable to obtain

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

which is necessary to show Lemma 2.

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.[14] 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.[15]

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

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

[15] 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 social 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.

3 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).

3.1 Canonical new Keynesian model

The loss function is quadratic as in (3) with $b = \kappa/\epsilon$, 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 $\mathbb{E}[\pi_{t+1}|\mathcal{G}_t^n]$.

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:[16]

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

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

[16] 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.

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

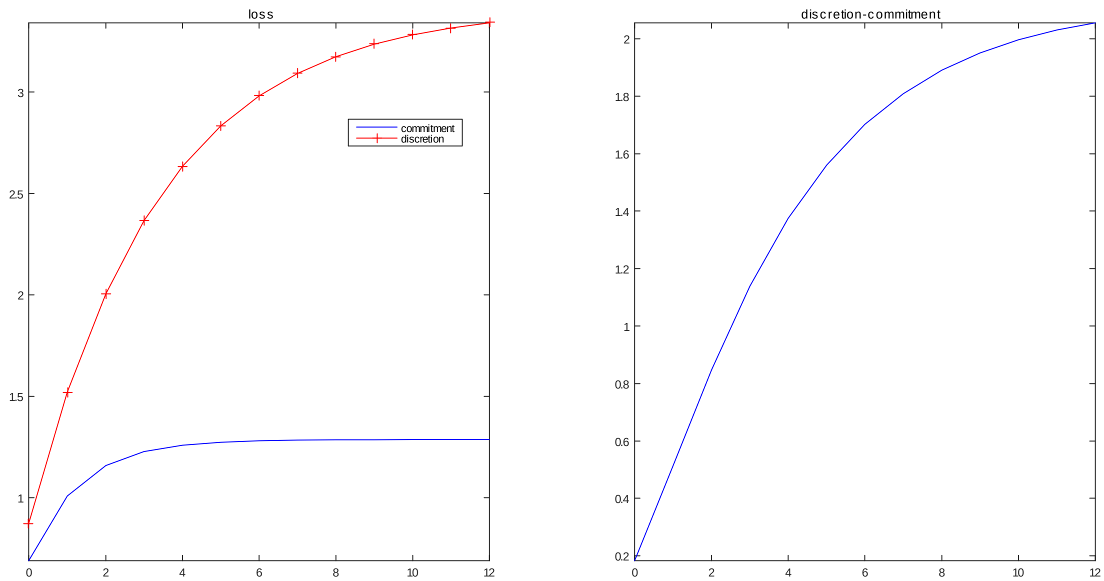

Figure 1: Loss under Commitment and Discretion

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 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

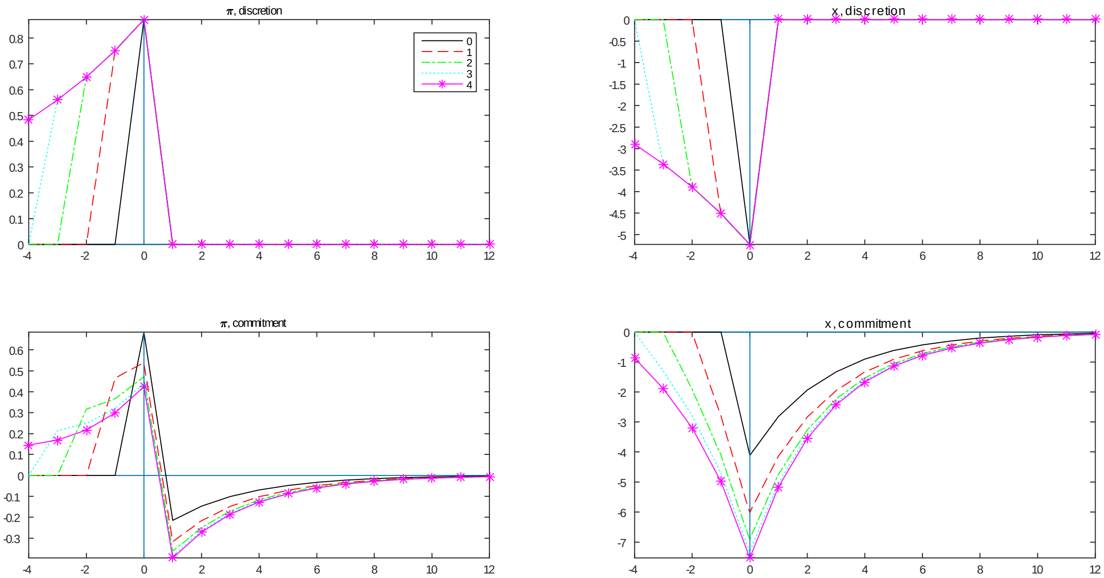

Figure 2: Impulse Responses: Commitment and Discretion

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

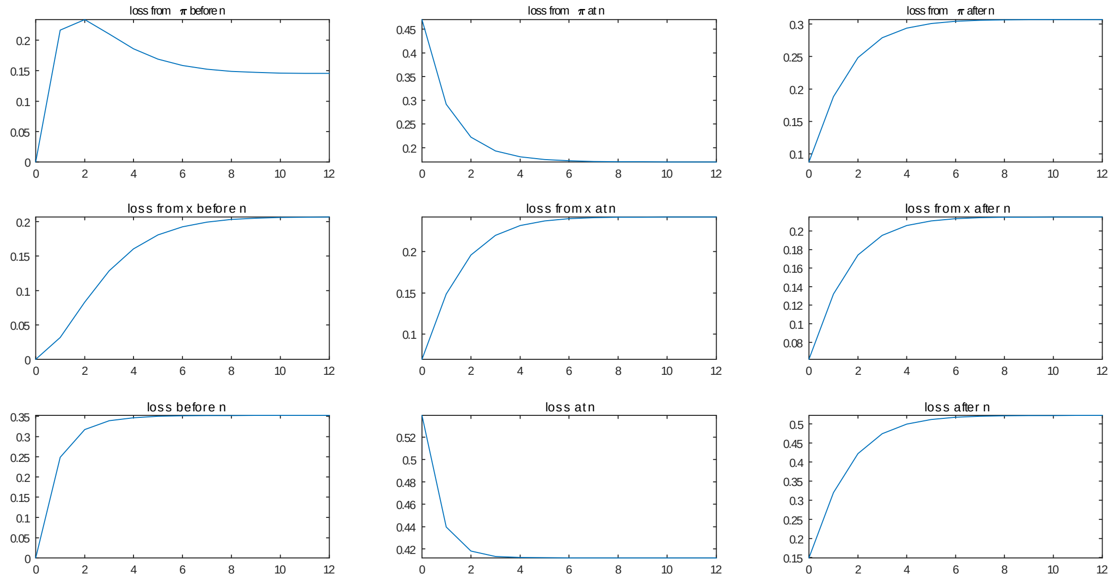

Figure 3: Loss by Timing

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.

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 ϕ of price setters are assumed to set prices P_t^B following a simple rule:

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

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.[17]

[17] When $\gamma = 0$, this reduces to the standard model with price indexation in e.g. Woodford (2003).

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

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

subject to the hybrid new Keynesian Phillips curve:

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

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

3.2.1 Results

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

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

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

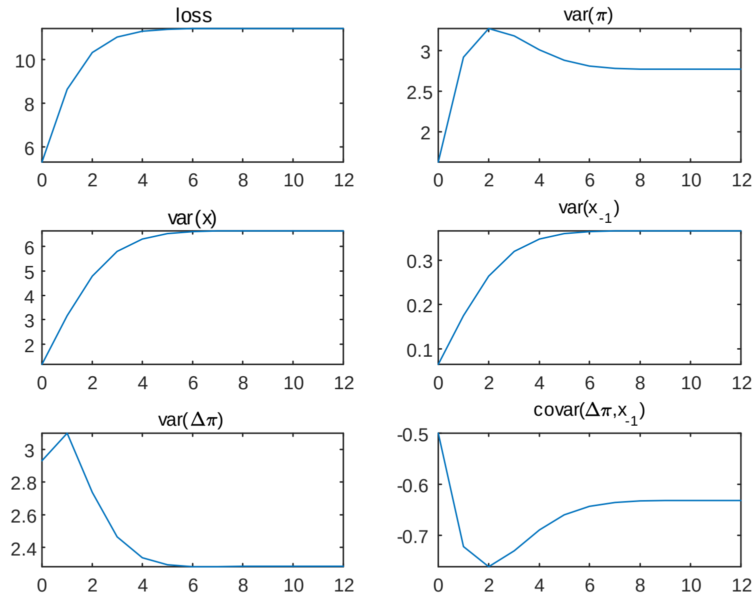

Figure 4: Terms in the Loss Function: Indexation

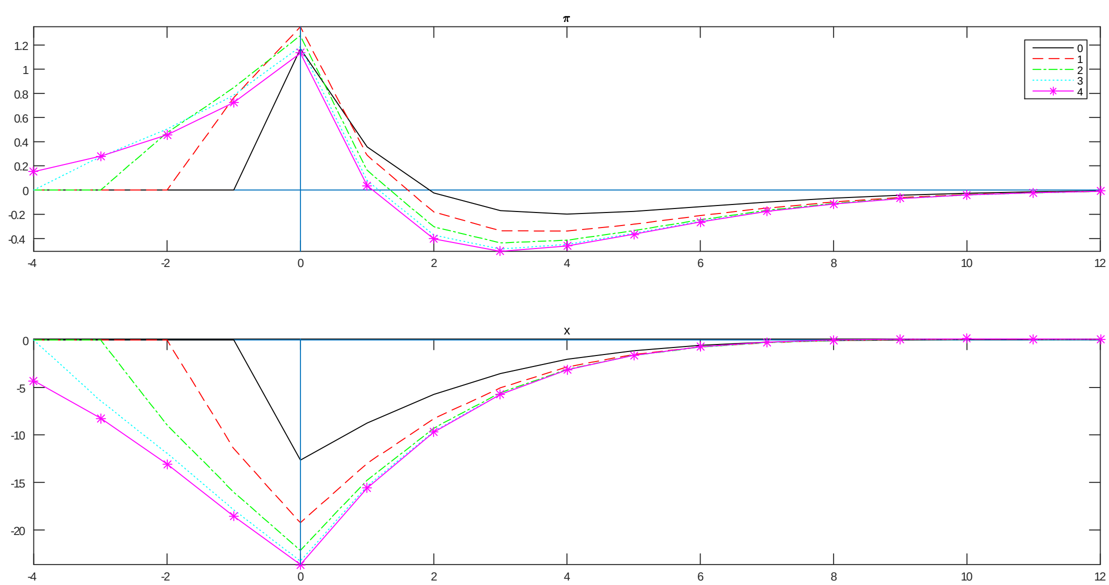

Figure 5: Impulse Responses: Indexation

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 / 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.

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 $I''(1) = \varepsilon_\psi$. Variable with upper bar denote level variables, while those without it are log deviations from steady states.

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

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

subject to the new Keynesian Phillips curve:

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

and the resource constraint:

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

where Y_t denotes the output.[18]

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: $\rho_y := \eta\phi_h + \frac{\phi_h}{\phi_h - 1}\omega_p$, $\rho_k := \rho_y - \eta$, $k := \frac{1-\phi_h^{-1}}{\beta^{-1}-(1-\delta)}$, $\omega := \omega_\omega + \omega_p$, $\omega_\omega := \eta\phi_h$, and $\psi := 1 + \frac{\varepsilon(\rho_y - \omega)\eta}{\rho_k}$.

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: the response of marginal costs is magnified as n increases, and the inflation response upon realization of a shock

[18] 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

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

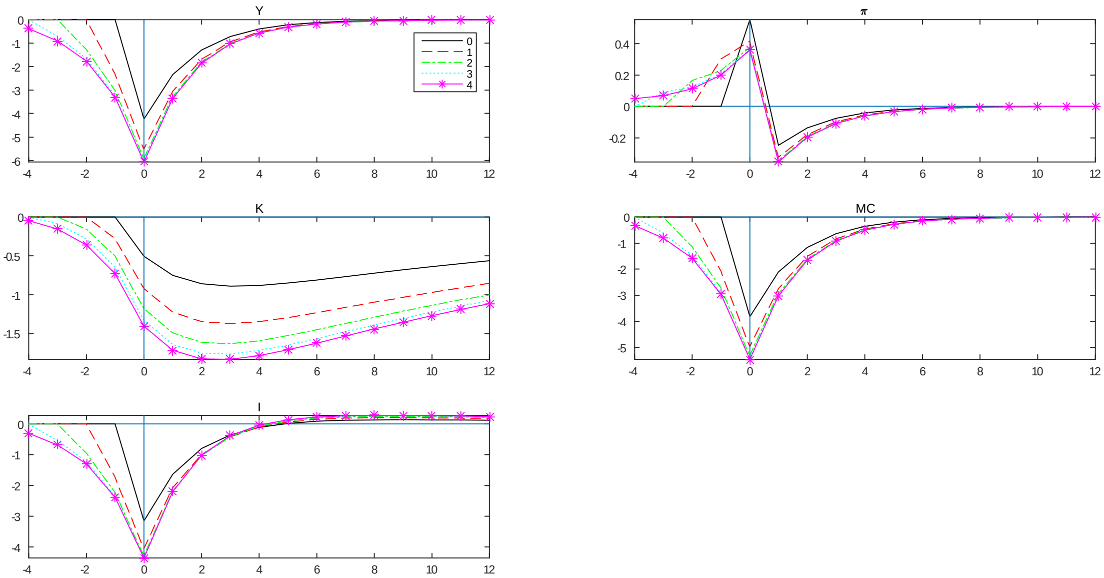

Figure 6: Impulse Responses: Endogenous Capital

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

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

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

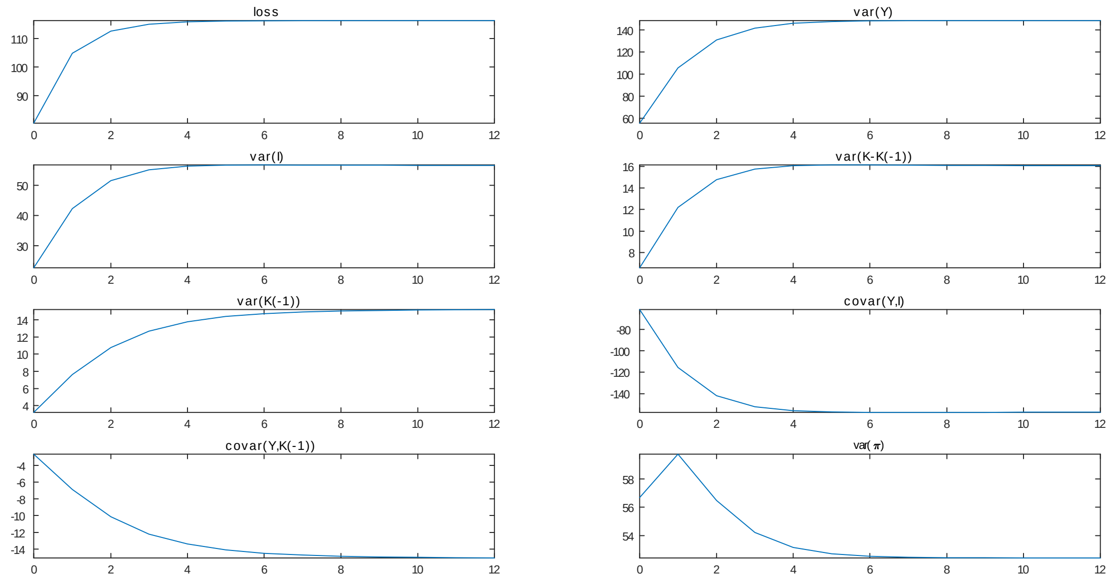

Figure 7: Terms in the Loss Function: Endogenous Capital

with price indexation as examined above. Again, there exists the expected virtue of ignorance.

4 Conclusion

How should monetary policy be designed when the central bank has private information about future economic conditions? We show that social welfare deteriorates when the private sector is made better-informed about future distortionary shocks or policy goals. 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 better than the private sector.

In the model considered in this paper, the private sector is assumed to have less information than does the central bank. More realistic situation may be that private agents obtains some information about future economic conditions which the central bank may not. It will be intriguing to investigate how its information is transmitted during the play of such a game with private information, and whether some communication can enhance social welfare. Other possible extensions are to consider non-linear new Keynesian models to examine whether information revelation is still undesirable, a non-benevolent central bank whose objective function depends on its private information possibly through non-pecuniary benefits (e.g. announcing accurate forecast of future economic conditions by itself increases its payoff), and the possibility that the central bank's private information revelation can resolve Knightian uncertainty the private sector faces. They are left for our future research.

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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,

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

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.