Optimal Central Bank Disclosure in a Business Cycle Model

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Abstract

I study the social value of information in a New Keynesian model of monopolistic price-setting with dispersed information, where the central bank can choose what information to share with the public. Under flexible prices, more disclosure is welfare improving: it reduces price dispersion and moves the economy closer to the first-best allocation. Under Calvo [1983] price stickiness, however, disclosure is detrimental to welfare, because of the additional price dispersion induced by the asynchronous adjustment in prices. If the price stickiness is due to quadratic adjustment costs, as in Rotemberg [1982], disclosure is detrimental to welfare as well: prices respond more to more precise information, increasing the adjustment cost. These results challenge the conventional wisdom found in the literature. Finally, I quantify the effects of disclosure on welfare. To do so, I bring the analysis closer to the DSGE paradigm and introduce physical capital into the model. Under flexible prices, I find that moving from no disclosure at all to full disclosure is equivalent to a permanent increase in the annual steady-state consumption level of 0.35%. However, when prices are sticky, disclosure generates a welfare loss of 0.24% in annual consumption. Thus, the social value of disclosure is sensitive to the presence of price stickiness, and disclosure has negative effects on welfare in the preferred specification.

Keywords: Central Bank transparency, social value of information, business cycles.

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I appreciate comments from attendees to the Northwestern Macroeconomics lunch seminar.
1 Introduction

A large number of central banks have increased their transparency over the years. Nowadays, policymakers are more willing to disclose their forecasts and to reveal their beliefs about the state of the economy. This shift towards more transparency reflects concerns that the central bank might have about the information available to agents in the economy. Providing more accurate information to economic agents diminishes the uncertainty they face about aggregate economic activity, and this can be welfare improving. It also reduces information heterogeneity, since announcements made by the central bank constitute public signals observed by every agent in the economy. However, these public signals are based on the private information of the central bank, which can be noisy. Therefore, announcements can increase the response of economic outcomes to noise, and this can have negative effects on welfare. Given these opposite effects on welfare, is transparency socially desirable? Should the central bank disclose more information? And more importantly: should we care at all? Are the effects of more disclosure on welfare quantitatively important?

In this paper I study the relation between disclosure of information by the central bank and social welfare in the context of a simple New Keynesian model. The New Keynesian paradigm has been widely used to address monetary policy questions and to perform quantitative welfare analysis. First, I consider the simplest version, without price stickiness or capital accumulation. This is the case that has been analyzed by the literature before. Under flexible prices, more disclosure is welfare improving, and this result coincides with what was found by Hellwig [2005], Angeletos et al. [2011] and others. Then, I study the social value of information when there is price stickiness. Under sticky prices, disclosure is detrimental to welfare, challenging the conventional wisdom found in the literature. Finally, I proceed to quantify the effects of disclosure on welfare. In order to do so, I need a framework more suitable to perform quantitative welfare analysis. With this goal in mind, I extend the model to allow for physical capital accumulation. I find that moving from no disclosure at all to full disclosure is equivalent to a permanent increase in the annual steady-state consumption level of 0.35%. However, when prices are sticky, disclosure generates a welfare loss of 0.24% in annual consumption. Thus, disclosure can be harmful, and its effect on welfare is modest but economically significant.

In more detail, I consider a model of monopolistic price-setting with dispersed information and price stickiness as in Calvo [1983], where the central bank can choose what information to share with the public. In the model, the economy is hit by an aggregate productivity shock. The central bank receives a noisy private signal about productivity, and this information is used to make public announcements and to set the nominal interest rate, following a Taylor rule. Producers do not observe aggregate productivity, but they know their own idiosyncratic productivity level. The idiosyncratic productivity depends on the aggregate productivity,
and can be used as a noisy signal about the aggregate variables. Producers also observe the announcement of the central bank. Using this information, they set their price, when allowed to do so.

With this model in hand, I analyze the social value of disclosure. The literature has concentrated exclusively in the case of flexible prices, when imperfect information is the only source of nominal rigidity (e.g., Morris and Shin [2002], Hellwig [2005], Angeletos et al. [2011]). In my framework, when prices are flexible, more precise disclosure of the information of the central bank is welfare improving. Price setters coordinate more about more precise public signals, and rely less in their private and dispersed information. This reduces cross-sectional price dispersion. At the same time, more precise information moves the equilibrium allocation closer to the full information allocation, which coincides with the first best, reducing the variance of the output gap. Both effects are welfare improving. This result coincides with what has been found previously for similar models.

However, the social value of information has not been analyzed when there is both imperfect information and some additional source of price stickiness. This case is relevant, since price rigidity is at the heart of the New-Keynesian paradigm, and virtually all modern macroeconomic models display one form or another of price stickiness. The literature on the social value of information has ignored price stickiness in part because conventional wisdom dictates that the welfare properties of the economy with price stickiness are well approximated by the welfare properties of the flexible-price economy. It is implicitly assumed that if public information is good under flexible prices, it is also good under sticky prices. Shockingly, the conventional wisdom is wrong in this case. Using a standard quarterly calibration, I find that more precise disclosure is detrimental to welfare when producers face price stickiness as in Calvo [1983].

In this model, price dispersion arises because producers face dispersed private signals (idiosyncratic productivity). When producers also face a Calvo price stickiness, additional price dispersion arises because some producers cannot adjust prices and do not respond to the most recent realization of the shocks. The ex-ante expected value of this additional source of price dispersion is proportional to the variance of inflation. When disclosure becomes more precise, the variance of inflation increases, because the producers that adjust prices react more to the noise contained in the public announcements. This increases price dispersion, and if the price stickiness is strong enough, this effect dominates. Therefore, for medium/high degrees of price stickiness, more precise disclosure can be detrimental to welfare.

Another commonly used source of price stickiness are quadratic adjustment costs, as in Rotemberg [1982]. When producers face reasonably calibrated quadratic adjustment costs, more disclosure is detrimental to welfare. In this case, the expected value of the quadratic adjustment costs increases. The reason, again, is that producers respond more strongly to the public signal, and adjust prices comparatively more. This effect dominates welfare for
medium/high degrees of price stickiness, causing a welfare loss.

Finally, I proceed to quantify the effects of disclosure on welfare. If the welfare gains/losses associated with disclosure are negligible, then there is no point in discussing the desirability of transparency. I show that this is not the case. To build a framework more suitable to perform quantitative analysis, I introduce physical capital in the model. Investment and endogenous capital accumulation are an essential part of modern macroeconomic models, and this modification brings the analysis closer to the DSGE paradigm (Christiano et al. [2005], Smets and Wouters [2007]). The presence of physical capital increases the size of the welfare gains/losses derived from more disclosure. This is due to the fact that production becomes more responsive to information through the presence of an additional production factor.

This paper contributes to the literature on the social value of information in several directions. First, I analyze the value of public information disclosure in a truly dynamic setting, where households work under an Euler equation and where today’s pricing decisions affect tomorrow’s outcomes. In particular, I explicitly analyze the role played by exogenous price stickiness. Second, I consider a central bank facing imperfect information, and study the social value of disclosing the information of the central bank. This differs from the standard approach, which assesses the social value of public exogenous information, and not the disclosure of private information of the policymaker. Third, I consider the role that physical capital plays in the social value of information, which has not been analyzed before. This allows me to quantify the gains/losses derived from more precise disclosure under a framework that is better suited for quantitative welfare analysis.

The paper is organized as follows: Section 2 presents the model; Section 3 finds the rational expectations linear equilibrium; Section 4 studies the social value of disclosure under flexible and sticky prices; Section 5 explores the interaction between physical capital accumulation and disclosure; the last section concludes.

2 The model

The economy is inhabited by a continuum of households, a final good producer and the central bank. Each household is composed of an intermediate good producer and a consumer. The intermediate good producers use labor to assemble their good under monopolistic competition, and face sticky prices a la Calvo [1983], heterogeneous productivity shocks and imperfect information about aggregate shocks. The final good producer aggregates the intermediate goods and sells the final good to the consumers. Finally, the policymaker sets the nominal interest rate following a Taylor rule, and makes public announcements about the state of the economy.
2.1 Final good producers

The final good producer uses the intermediate goods to produce the final output according to

\[ Y_t = \left[ \int_0^1 (Y_{i,t})^{\theta-1} d\theta \right]^{\frac{\theta}{\theta-1}}, \]

where \( Y_{i,t} \) is the intermediate good produced by household \( i \).

The final good producer maximizes profits, taking the market prices as given. The demand for intermediate good \( i \) by the final good producer is given by

\[ Y_{i,t} = \left( \frac{P_{i,t}}{P_t} \right)^{-\theta} Y_t, \]

where

\[ P_t = \left[ \int_0^1 (P_{i,t})^{1-\theta} d\theta \right]^{\frac{1}{1-\theta}} \]

is the Dixit-Stiglitz price index.

2.2 Households

There is a continuum of households distributed uniformly on the unit interval. Each household is constituted by two agents: a producer specialized in the production of good \( i \), and a consumer. At the beginning of each period \( t \), the producer sets the price for its good under imperfect information. Once the price for its good is set, the household commits to produce as much of the good \( i \) as demanded. At the end of period \( t \), the consumer goes shopping, learns the realization of all the shocks hitting the economy, supplies the labor required to satisfy the demand for good \( i \) and consumes.

Household \( i \)’s preferences are given by

\[ U_{i,t} = E_{i,t} \left[ \sum_{j=0}^{\infty} \beta^j \left( C_{i,t+j}^{1-\sigma} - \frac{1}{1-\sigma} - \psi N_{i,t+j}^{1+\eta} \right) \right], \]

where \( C_{i,t+j} \) denotes consumption of the aggregate good by consumer \( i \) and \( N_{i,t+j} \) represents labor effort.

In order to produce \( Y_{i,t} \) units of good \( i \), household \( i \) needs to supply

\[ N_{i,t} = \frac{1}{\alpha} \left( \frac{Y_{i,t}}{A_{i,t}} \right)^{\alpha} \]

units of labor, where \( \alpha > 1 \) and \( A_{i,t} \) is the productivity level specific to producer \( i \). I assume
that \( a_{i,t} = \ln (A_{i,t}) \) follows the process

\[
a_{i,t} = a_t + \xi_{i,t},
\]

where \( a_t \) is the aggregate component of productivity, and \( \xi_{i,t} \sim N \left( 0, \tau^{-1}_\xi \right) \) is i.i.d. over time and across the population, and independent of all other shocks in the economy. The aggregate productivity, \( a_t \), follows the AR(1) process

\[
a_t = \rho a_{t-1} + \mu_t,
\]

where \( \mu_t \sim N \left( 0, \tau^{-1}_\mu \right) \) is independent of any other shock and i.i.d. over time.

Aggregate productivity is the fundamental source of uncertainty: before market activities occur, agents do not know the current realization of \( a_t \). At the beginning of each period, intermediate producers observe their own productivity \( a_{i,t} \), and use it as a signal to make inferences about the aggregate component \( a_t \). In addition, all households observe a public signal concerning the private information of the central bank,

\[
z_t = s_t + v_t,
\]

where \( s_t \) denotes the information of the central bank about \( a_t \) (to be specified in the next subsection), and \( v_t \sim N \left( 0, \tau^{-1}_v \right) \) is i.i.d. over time, and independent of all other shocks in the economy.

Finally, I assume that the aggregate price level and the aggregate output in the previous period, \( P_{t-1} \) and \( Y_{t-1} \), are commonly known at the beginning of date \( t \). Therefore, producer \( i \)'s information set at the beginning of period \( t \), \( I_{i,t} \), is given by

\[
I_{i,t} = \{ a_{i,t-j}, z_{t-j}, y_{t-1-j}, p_{t-1-j} \}_{j=0}^{\infty},
\]

where lowercase variables denote log-deviations from the steady state of uppercase variables.

Households face an exogenous price stickiness a la Calvo [1983]. With probability \( \nu \), household \( i \) cannot change the price it charges for its variety in the current period, and has to set \( p_{i,t} = p_{i,t-1} \). With probability \( 1 - \nu \) the intermediate producer can re-optimize, choosing \( p_{i,t} \) optimally.

The objective of the household is to maximize the discounted expected value of utility, \( U_{i,t} \), subject to the information constraints faced by its members, the caprices of the Calvo
fairy, and the sequence of budget constraints

\[ P_{t+j} C_{i,t+j} + B_{i,t+j} = (1 + T^s) P_{i,t+j} Y_{i,t+j} + B_{i,t+j-1} R_{t+j-1} + X_{t+j}, \]

where \( X_{t+j} \) are lump sum transfers, \( B_{i,t+j} \) is the holding of nominal financial assets, \( R_{t+j} \) is the nominal gross interest rate, \( P_{t+j} \) is the consumption price index and \( T^s \) is the subsidy rate to intermediate producers. As usual, the net subsidy \( T^s \) is chosen to eliminate the distortions arising from the monopolistic power of the intermediate producers. The transfers \( X_{t+j} \) are exogenous to the households, and satisfy

\[ X_{t+j} = -T^s \int_0^1 P_{i,t+j} Y_{i,t+j}^t \, dt. \]

To summarize, each household is composed of a producer and a consumer, who share the same objective function, the discounted expected value of utility, \( U_{i,t} \), but optimize it under different information sets. At the beginning of period \( t \), the intermediate producer seeks to maximize \( U_{i,t} \) conditional on the available information \( \mathcal{I}_{i,t} \), by choosing the price level \( P_{i,t} \), if she is allowed to do so. After all the aggregate shocks are observed, at the end of period \( t \), the consumer seeks to maximize \( U_{i,t} \), under perfect information, by choosing consumption and asset holdings. Finally, I assume that households are able to perfectly diversify all idiosyncratic risk (i.e., they are fully insured). Thus, in equilibrium, all households have the same asset holdings and make the same consumption decisions.

One alternative, and completely equivalent, interpretation of the behavior of the household in this model is the following: each household is composed of a continuum of workers, sent at the beginning of the period to work for an intermediate producer. Each intermediate producer lives in an “information” island, as in Angeletos et al. [2011], isolated from the aggregate economy, and operates under the information set \( \mathcal{I}_{i,t} \). At the end of the period, each worker returns to the household, their income is aggregated, and the household consumes and saves.

### 2.3 Central bank

The central bank observes \( c_{t-1}, p_{t-1} \) and receives the private signal \( s_t \) about the productivity process,

\[ s_t = a_t + \varepsilon_t, \]

where \( \varepsilon_t \sim N(0, \tau^{-1}_\varepsilon) \) is i.i.d. over time, and independent of all other shocks in the economy.
Then, the information set of the central bank at the beginning of period $t$ is

$$\mathcal{I}_{CB,t} = \{s_{t-j}, c_{t-1-j}, p_{t-1-j}\}_{j=0}^{\infty}. $$

Using these observable variables, the central bank sets the log-deviation from steady state of the gross nominal interest rate, $r_t$, following the rule

$$r_t = E [\phi (p_t - p_{t-1}) | \mathcal{I}_{CB,t}], $$

where $\phi > 1$ is the reaction parameter of the interest rate rule.

Finally, the central bank is able to produce and communicate the public signal

$$z_t = s_t + v_t. $$

The central bank can choose the precision of the public signal, $\tau_v$. When $\tau_v = 0$, the central bank produces uninformative signals about the productivity $a_t$. When $\tau_v \to \infty$, the central bank completely reveals its private information to the intermediate producers. Thus, the parameter $\tau_v$ summarizes the level of disclosure and transparency of the central bank.

### 3 Equilibrium and welfare

In this section, I find the unique symmetric stationary rational expectations linear equilibrium, taking the monetary policy rule and the precision of public signals as given, for the log-linearized version of the model. First I describe the solution to the price setting problem. Then, I characterize the behavior of consumption and inflation in equilibrium. Finally, I derive the welfare criterion that will be used to evaluate different disclosure policies. From now on, lowercase variables denote log-deviations from the steady state of uppercase variables.

#### 3.1 Intermediate producers

Consider first the case where there is no Calvo stickiness and price setters observe the aggregate shocks. The optimal relative price, after taking into account the subsidy to production, equals the real marginal cost:

$$p^*_i,t - p_t = mc_{i,t}. $$

The real marginal cost faced by the producer at the end of the period is

$$mc_{i,t} = w_{i,t} + (\alpha - 1) y_{i,t} - \alpha a_{i,t}, $$
where $w_{i,t}$ is the marginal rate of substitution between labor effort and consumption,

$$w_{i,t} = \eta n_{i,t} + \sigma c_{i,t}.$$  

From the production technology, labor effort is

$$n_{i,t} = \alpha (y_{i,t} - a_{i,t}),$$

where $y_{i,t}$ satisfies, from the final-good producer’s demand,

$$y_{i,t} = -\theta (p_{i,t} - p_t) + y_t.$$  

After substituting in all these conditions, the target price becomes

$$p_{i,t}^* = p_t + (1 - r) \left( y_t - a_{i,t} + \frac{\sigma c_{i,t} - y_t}{\alpha (1 + \eta)} \right),$$

where $r \equiv 1 - \frac{\alpha (1 + \eta)}{1 + \theta (\alpha (1 + \eta) - 1)}$ measures the degree of strategic complementarity in price setting. Under perfect information, the producer sets $p_{i,t} = p_{i,t}^*$ if not facing the Calvo rigidity.

I assume, however, that producers have imperfect information and might not be able to adjust their price at every period. To find the optimal price set by producer $i$ when it is allowed to re-optimize, I first find the quadratic approximation to the period $t$ utility loss.

**Lemma 1.** The instantaneous utility loss for the producer $i$ can be approximated as

$$\frac{1}{2} \nu^{1-\sigma} \theta \left( (\sigma - 1) \theta + \frac{\alpha (1 + \eta)}{1 - r} \right) \left( p_{i,t} - p_{i,t}^* \right)^2.$$  

The loss is minimized when setting $p_{i,t} = p_{i,t}^*$. Under imperfect information, the producer must do its best to forecast and track $p_{i,t}^*$. Furthermore, because of the Calvo rigidity, the price setter must take into account that, with probability $\nu$, the price set today will also hold tomorrow.

In particular, the problem faced by producer $i$ when it can adjust its price at time $t$ is equivalent to

$$\min_{p_{i,t}^{\text{adj}}} \quad E \left[ \sum_{j=0}^{\infty} (\beta \nu)^j \left( p_{i,t}^{\text{adj}} - p_{i,t+j}^* \right)^2 | I_{i,t} \right]$$

s.t.  

$$p_{i,t}^* = p_t + (1 - r) \left( y_t - a_{i,t} + \frac{\sigma c_{i,t} - y_t}{\alpha (1 + \eta)} \right),$$
and the optimal price is

\[ p_{i,t}^{adj} = (1 - \beta\nu) E \left[ \sum_{j=0}^{\infty} (\beta\nu)^j p_{i,t+j}^* |I_{i,t} \right]. \]

As usual, the optimal price is the discounted sum of present and future expected marginal costs.

### 3.2 Rotemberg price stickiness

Another form of price stickiness commonly used in the New Keynesian literature is to assume that firms face quadratic adjustment costs in price setting. This is the approach followed by Rotemberg [1982]. In particular, suppose that producers are free to adjust their price every period \((\nu = 0)\), but face the cost

\[ \text{Adj}_{i,t} = \frac{\varphi}{2} \left( \frac{P_{i,t}}{P_{i,t-1}} - 1 \right)^2 Y_t, \]

where \(\varphi \geq 0\) parameterizes the degree of price stickiness.

In this case, the instantaneous utility loss for the producer \(i\) is proportional to

\[ \left( p_{i,t} - p_{i,t}^* \right)^2 + \tilde{\varphi} \left( p_{i,t} - p_{i,t-1} \right)^2, \]

where \(\tilde{\varphi} \equiv \frac{1-r}{\alpha\theta(1+\eta)}\varphi\). The utility loss now takes into account the foregone consumption associated with the quadratic price adjustment cost. The problem faced by producer \(i\) at time \(t\) is equivalent to

\[
\min_{p_{i,t}^{Rot}} E \left[ \sum_{j=0}^{\infty} \beta^j \left( \left( p_{i,t} - p_{i,t}^* \right)^2 + \tilde{\varphi} \left( p_{i,t} - p_{i,t-1} \right)^2 \right) |I_{i,t} \right]
\]

s.t. \( p_{i,t}^* = p_t + (1-r) \left( y_t - a_{i,t} + \frac{\sigma c_{i,t} - y_t}{\alpha (1+\eta)} \right), \)

and the optimal price satisfies

\[ p_{i,t}^{Rot} = E \left[ \frac{\beta\tilde{\varphi}p_{i,t+1} + p_{i,t}^* + \tilde{\varphi}p_{i,t-1}}{1 + (1+\beta)\tilde{\varphi}} |I_{i,t} \right]. \]

### 3.3 Consumers

Consumers make their choices under perfect information, because the aggregate shocks are revealed when shopping at the end of the period. Since households are able to perfectly diversify all idiosyncratic risk, all consumers choose the same consumption level, and \(c_{i,t} = c_t\).
for all $i$.

The behavior of the consumers is characterized by the Euler equation
\[ c_t = \frac{1}{\sigma} (-r_t + E_t [p_{t+1} - p_t]) + E_t [c_{t+1}] . \]

Finally, the aggregate resource constraint reads $y_t = c_t$.

### 3.4 Equilibrium

To find the linear equilibrium, I follow a “guess and verify” approach. I assume that the optimal price, $p_{i,t}^{opt}$, follows the linear rule
\[ p_{i,t}^{opt} = p_{t-1} + (1 - \gamma_p) (p_{i,t-1} - p_{t-1}) + \gamma_a a_{t-1} + \gamma_\xi (a_{i,t} - \rho a_{t-1}) + \gamma_z (z_t - \rho a_{t-1}) , \]

where $opt \in \{adj, Rot\}$ indexes either Calvo or Rotemberg price stickiness. I guess that consumption satisfies
\[ c_t = c_a a_{t-1} + c_\mu \mu_t + c_\varepsilon \varepsilon_t + c_v v_t , \]

for some constants $\gamma_a$, $\gamma_p$, $\gamma_\xi$, $\gamma_z$, $c_a$, $c_\mu$, $c_\varepsilon$ and $c_v$. Then, I solve the optimization problems of the consumer and the intermediate producers, and verify that the optimal actions are linear functions, confirming the guess.

The rules are measurable with respect to the information available to each agent when making their decision. In the price rule, the parameter $\gamma_\xi$ measures the importance of idiosyncratic productivity (and therefore, private information), whereas $\gamma_z$ measures the importance of public information.

Consider the aggregate price index induced by the linear price-setting rule followed by the producers. At period $t$, a fraction $\nu$ of producers cannot adjust their price. Since these households are drawn at random, their average price equals $p_{t-1}$. It follows that
\[ p_t = \nu p_{t-1} + (1 - \nu) \int p_{i,t}^{opt} di = p_{t-1} + (1 - \nu) (\gamma_a a_{t-1} + \gamma_\xi \mu_t + \gamma_z (z_t - \rho a_{t-1})) , \]

where the integral is taken over the set of producers that adjust prices in period $t$. Note that this equation is valid as well if $\nu = 0$, as in the flexible price case or in the Rotemberg case.

Substituting the aggregate price in the interest rate rule, it follows that
\[ r_t = \phi (1 - \nu) (\gamma_a a_{t-1} + \gamma_\xi E [\mu_t | ICB,t] + \gamma_z (z_t - \rho a_{t-1})) , \]

where
\[ E [\mu_t | ICB,t] = \frac{\tau_\varepsilon}{\tau_a + \tau_\varepsilon} (s_t - \rho a_{t-1}) . \]
Using the expression for $p_{t+1}$ from the linear price rule, and the expression for $c_{t+1}$ from the linear consumption rule, it follows that

$$E_t [p_{t+1} - p_t] = (1 - \nu) \gamma_a a_t,$$

$$E_t [c_{t+1}] = c_a a_t.$$

Substituting these quantities in the Euler equation, it follows that $c_t$ is a linear function of $a_{t-1}$, $\mu_t$, $\varepsilon_t$ and $\nu_t$, verifying the guess.

To verify the guess on the optimal price, I consider the Calvo stickiness and the Rotemberg stickiness separately. In the Calvo case, note that the optimal price satisfies the recursive equation

$$p_{i,t}^{adj} = E \left[ (1 - \beta \nu) \left( p_{i,t}^* \right) + \beta \nu p_{i,t+1}^{adj} | I_{i,t} \right],$$

where $p_{i,t+1}^{adj} = (1 - \beta \nu) E \left[ \sum_{j=0}^{\infty} (\beta \nu)^j p_{i,t+1+j}^* | I_{i,t+1} \right]$ is the price that the producer would set if it could adjust it in period $t+1$.

In the Rotemberg case, a similar recursive equation is satisfied:

$$p_{i,t}^{Rot} = E \left[ \frac{\beta \tilde{\varphi} p_{i,t+1}^{Rot} + p_{i,t}^* + \tilde{\varphi} p_{i,t-1} | I_{i,t} }{1 + (1 + \beta) \tilde{\varphi}} \right],$$

where $p_{i,t+1}^{Rot}$ is the price that the producer will set in period $t + 1$.

Noting that in equilibrium $y_t = c_t = c_{i,t}$, substituting the guess for $p_t$, $c_t$, $p_{i,t}^{opt}$ and the process $a_t$, and taking expectations over the shocks $\mu_t$, $\varepsilon_t$ and $\nu_t$, it follows that $p_{i,t}^{adj}$ is a linear function of $p_{t-1}$, $a_{t-1}$, $a_{i,t} - \rho a_{t-1}$ and $z_t - \rho a_{t-1}$; it also follows that $p_{i,t}^{Rot}$ is a linear function of the same variables and of $p_{i,t-1}$. This confirms the guess about $p_{i,t}^{adj}$ and $p_{i,t}^{Rot}$, and gives expressions for the coefficients $\gamma_a$, $\gamma_p$, $\gamma_\xi$ and $\gamma_z$, as functions of the parameters of the model.

The next proposition summarizes the results presented in this section.

**Proposition 1.** There exists a rational expectations equilibrium in which producer $i$ follows the pricing rule (when allowed to adjust)

$$p_{i,t} = p_{t-1} + (1 - \gamma_p) (p_{i,t-1} - p_{t-1}) + \gamma_a a_{t-1} + \gamma_\xi (a_{i,t} - \rho a_{t-1}) + \gamma_z (z_t - \rho a_{t-1}),$$

the aggregate price is given by

$$p_t = p_{t-1} + (1 - \nu) (\gamma_a a_{t-1} + \gamma_\xi \mu_t + \gamma_z (z_t - \rho a_{t-1})).$$
and consumption follows the rule

\[ c_t = c_a a_{t-1} + c_\mu \mu_t + c_\varepsilon \varepsilon_t + c_v v_t, \]

for some coefficients \( \gamma \) and \( c \).

Under Rotemberg price stickiness, \( \nu = 0 \) and \( 0 < \gamma_p < 1 \). Under Calvo price stickiness, \( \nu \geq 0 \) and \( \gamma_p = 1 \).

Furthermore, \( c_a, \gamma_a, \gamma_p \) and \( c_\mu - c_\varepsilon \) are independent of the precision (variance) of the shocks hitting the economy.

### 3.5 Welfare criterion

Let

\[ W = E \left[ \sum_{t=0}^{\infty} \beta^t \left( C_{t-1}^{1-\sigma} - \psi \int_0^1 N_{i,t}^{1+\eta} \right) \right] \]

denote the aggregate welfare. Define the welfare loss as \( L = (1 - \beta) (W - W^*) \), where \( W^* \) is the maximum possible value attainable by \( W \) (i.e., the discounted expected utility under the first-best allocation). As shown in Adam [2007], \( L \) can be approximated as follows:

**Proposition 2.** The expected welfare loss can be approximated as

\[
L = Y^{1-\sigma} \alpha (1+\eta) \left[ \frac{\theta}{1 - r} E \left[ \int_0^1 (p_{i,t} - p_t)^2 \, di + \tilde{\varphi} \int_0^1 (p_{i,t} - p_{i,t-1})^2 \, di \right] + \left( 1 + \frac{\sigma - 1}{\alpha (1 + \eta)} \right) \text{Var} \left[ y_t - y_t^{eff} \right] + 2\theta E \left[ \int_0^1 (p_{i,t} - p_t) \xi_{i,t} \, di \right] + \theta (1 - r) \tau_{\xi}^{-1} \right],
\]

where \( r = 1 - \frac{\alpha(1+\eta)}{1+\theta(\alpha(1+\eta)-1)} \), \( \tilde{\varphi} = \frac{1-r}{\alpha(1+\eta)} \varphi \), and \( y_t^{eff} = \frac{\alpha(1+\eta)}{\alpha(1+\eta)+\sigma-1} a_t \) is the efficient (first-best) level of aggregate output.

The relative merits of different disclosure policies are evaluated using this welfare loss. The loss is composed of four elements: first, the expected value of the cross-sectional price dispersion, \( E \left[ \int_0^1 (p_{i,t} - p_t)^2 \, di \right] \), which generates a welfare loss because of the desire of households to smooth consumption across varieties; second, the expected aggregate quadratic price adjustment cost; third, the variance of the output gap, \( \text{Var} \left[ y_t - y_t^{eff} \right] \), which measures the distance between equilibrium and efficient aggregate outcomes; and lastly, a component related to the covariance between the relative price of producer \( i \) and her productivity level: relatively more productive agents should produce more, and should charge a lower relative price.
4 Social value of disclosure: flexible vs sticky prices

In this section, I answer the following question: What is the social value of disclosure? Should the central bank disclose its private information to the price setters? Furthermore, I study the effect of more precise public information on the volatility of inflation, consumption and the nominal interest rate.

In the model, the central bank receives a private signal, $s_t$, about the level of aggregate productivity. The central bank can disclose its private information by publishing the signal $z_t = s_t + v_t$, where $v_t \sim N(0, \tau_v^{-1})$ is noise that the central bank adds to its public announcements. The parameter $\tau_v$ represents the precision of the noise added to the public signal. If the central bank decides to fully disclose its private information, $\tau_v \to \infty$, there is no residual variance in $v_t$, and all the producers observe $s_t = z_t$. If the central bank decides not to reveal anything, it can send a useless signal with zero precision, $\tau_v = 0$. Producers understand that the signal $z_t$ is pure noise and discard it. Finally, the central bank can choose an intermediate level of disclosure, represented by a finite but positive value of $\tau_v$.

Formally, I want to understand the effect of $\tau_v$ on the welfare loss $L$. The presence of the Calvo stickiness or the Rotemberg quadratic adjustment cost make it unfeasible to find a closed-form expression for the welfare loss, forcing me to rely on numerical analysis. Thus, I must find values for the parameters of the model.

4.1 Calibration

Table 1 presents the values chosen for the parameters of the model.

I use a quarterly frequency. Most parameter values are taken from the real business cycle literature (e.g., King and Rebelo [1999], Dufour et al. [2010]). It is important to note that for each level of Calvo price stickiness, $\nu$, there is a unique value for the scale parameter of the quadratic adjustment cost, $\phi$, such that the dynamic behavior of both economies is identical. Since the Calvo parameter has a simpler interpretation, I index the degree of price stickiness using $\nu$, and fix $\phi$ to the corresponding value.

The novel parameters are those related to the precision of the information received by the central bank, $\tau_{\epsilon}^{-1}$, and producers, $\tau_{\xi}^{-1}$. To calibrate them, I estimate the model, by maximum likelihood, using quarterly HP-detrended data on real GDP, inflation and the federal funds rate for the period 1986:2-2008:1, keeping the other parameters as given.
Table 1: Baseline calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$ Discount factor</td>
<td>0.99</td>
</tr>
<tr>
<td>$\eta$ Inv. Frisch elasticity</td>
<td>1</td>
</tr>
<tr>
<td>$\sigma$ Risk aversion</td>
<td>2</td>
</tr>
<tr>
<td>$\alpha$ Production function</td>
<td>$\frac{3}{2}$</td>
</tr>
<tr>
<td>$\phi$ Taylor rule</td>
<td>1.50</td>
</tr>
<tr>
<td>$\theta$ Elasticity of subst.</td>
<td>10</td>
</tr>
<tr>
<td>$\nu$ Calvo rigidity</td>
<td>0.60</td>
</tr>
<tr>
<td>$\tilde{\phi}$ Adjustment cost</td>
<td>3.7</td>
</tr>
<tr>
<td>$\rho$</td>
<td>0.75</td>
</tr>
<tr>
<td>$\sigma_a$</td>
<td>0.007</td>
</tr>
<tr>
<td>$\sigma_\varepsilon$</td>
<td>St. dev. signal central bank 0.004</td>
</tr>
<tr>
<td>$\sigma_\xi$ St. dev. firm productivity</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Aggregate productivity

<table>
<thead>
<tr>
<th>Information parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_\varepsilon$</td>
</tr>
<tr>
<td>$\sigma_\xi$ St. dev. firm productivity</td>
</tr>
</tbody>
</table>

4.2 No exogenous price stickiness

The literature often analyzes the social value of disclosure/public information in models of static price setting. In my model, this corresponds to the case in which the Calvo friction is not present, and/or there are no quadratic adjustment costs. In particular, assume that $\nu = \varphi = 0$. That is, producers can always adjust the price, and there is no exogenous price stickiness.

Figure 1 illustrates the effects of more precise disclosure on the expected value of the price dispersion, the variance of the output gap, the correlation between relative prices and idiosyncratic productivity, and the welfare loss. In a world of non-sticky-prices, more disclosure reduces price dispersion, because producers coordinate more around the more precise public signal. The variance of the output gap decreases since producers can track more closely productivity. This moves the economy closer to the perfect information equilibrium, which is efficient. Finally, note that producers put less weight on its own productivity as a signal about the aggregate productivity, and this reduces the magnitude (absolute value) of the covariance between relative prices and idiosyncratic productivity.

The decrease of both price dispersion and variance of output gap unambiguously generate a decrease in the welfare loss. These components dominate in the welfare criterion, and more disclosure is socially desirable when prices are not sticky. This result is in line with the results found by Hellwig [2005] and Angeletos et al. [2011].
4.3 Calvo sticky prices

Now, I focus on the Calvo price stickiness and consider the case $\nu > 0$. This case has not received much attention in the literature. Figure 2 summarizes the result for the preferred calibration of the model, summarized in Table 1. In particular, more precise disclosure is detrimental to welfare.

Price stickiness affects how price dispersion reacts to the precision of public information. As in the non-sticky-prices world, more precision induces producers to coordinate more about the public signal, in their desired price. However, this stronger response to public signals increases the response of the aggregate price to noise shocks. This increases the volatility in the inflation rate, and increases dispersion. Which effect dominates in equilibrium depends on the frequency of price adjustment, related to the parameter $\nu$.

To understand the intuition behind this result, consider the expression for price dispersion in the rational expectations equilibrium:

$$d = \gamma_2^2(\tau - 1) + \frac{\nu}{(1 - \nu)^2} E \left[ (p_t - p_{t-1})^2 \right].$$

Price dispersion is the sum of two components: first, the cross sectional variation that arises due to dispersed information, $\gamma_2^2(\tau - 1)$, and second, the cross sectional variation that arises due to the Calvo stickiness, $\frac{\nu}{(1 - \nu)^2} E \left[ (p_t - p_{t-1})^2 \right]$. When producers face dispersed information, their actions diverge due to the idiosyncratic...
noise of their private signals (their own individual productivity). The coefficient $\gamma_\xi$ dictates how strongly each producer reacts to its own information, and price dispersion increases when this response is larger. More precise public information induces producers to coordinate more about the public signal, reducing $\gamma_\xi^2$ and decreasing price dispersion. For $\nu$ close to zero, this effect dominates and price dispersion is reduced.

When producers are subject to sticky prices, cross sectional dispersion in prices arise due to the fact that some producers cannot adjust their prices today. This is summarized by the unconditional variance of the inflation rate, $E \left[ (p_t - p_{t-1})^2 \right]$. In this framework, as will be clear in the next subsection, inflation becomes more volatile with more informative public signals. If $\nu$ is large enough, this effect dominates, causing price dispersion to increase with the precision of public information.

### 4.4 Rotemberg price stickiness

Consider the presence of quadratic price adjustment costs. I set $\varphi$ to the value that delivers the same dynamic behavior as the one obtained under the preferred calibration for $\nu$. The response of welfare to disclosure is almost identical to the one under Calvo price stickiness. In this setting, price dispersion is given by

$$d = \frac{\gamma_\xi^2 \tau - 1}{1 - (1 - \gamma_p)^2}. $$
and it is due to the dispersion arising from private information, adjusted by the fact that price dispersion is persistent because of the adjustment cost. More precise public information induces producers to coordinate more about the public signal, reducing price dispersion.

The welfare loss now includes the expected value of the economy wide quadratic price adjustment cost. The cost is given by

$$E \left[ \int_0^1 \frac{\varphi}{2} (p_{i,t} - p_{i,t-1})^2 \, di \right] = \varphi \frac{\xi^2 \tau - 1}{1 - \gamma_p} + \frac{\varphi}{2} E \left[ (p_i - p_{i-1})^2 \right],$$

and it is the sum of two components: the first one, related to cross-sectional price dispersion, which decreases with more precise disclosure; and the ex-ante variance of inflation. When prices are adjusted more producers face a higher adjustment cost and inflation becomes more volatile.

As in the case with Calvo rigidity, inflation becomes more volatile with more informative public signals. If $\varphi$ is large enough, the increase in the ex-ante variance of inflation dominates, causing the quadratic adjustment costs to increase with the precision of public information. This is detrimental to welfare.

4.5 Volatility of output and inflation

In this subsection, I study the effects of more precise public information on output, inflation and the nominal interest rate. The dynamic behavior of the Calvo and Rotemberg economies is identical, and it is not necessary to distinguish which one is the source of price stickiness.

Under the baseline calibration, more precise disclosure of information increases the standard deviation of consumption, inflation and the nominal interest rate. The reason is that producers place a higher weight on more informative signals when setting prices. Since the announcement of the central bank contains noise, producers are responding more to noise shocks, increasing the volatility of economic aggregates.

In particular, consider the pricing decision. A high level of idiosyncratic productivity induces a reduction in the price set by the producer, because she faces a low marginal cost today. A positive public signal indicates that aggregate productivity is high, and all producers face a low marginal cost. Then, it forecasts that the aggregate price level will be lower, and this induces the producer to lower her own price. More precision in the public signal generates a shift from private to public information. Each producer relies more in the public signal and responds more to it. In aggregate, inflation and the interest rate respond more to the noise contained in the public signal, decreasing by more when the signal is large.

Consider now the consumption decision. Consumption is determined by the Euler equation. If both inflation and the interest rate decrease by more when responding to large public signals, consumption increases by more. Thus, more precise public information induces con-
Figure 3: Volatility and the precision of public information

sumers to place a larger, positive weight on the noise shocks of the signals. All these effects increase the volatility of inflation, consumption and the nominal interest rate.

Finally, consider the general equilibrium effect. More precise public information induces a stronger response of consumption and inflation to noise shocks. In particular, a positive public signal induces a larger decrease in inflation. Due to the strategic complementarity in price setting, each producer has stronger incentives to decrease her own price. This is partially compensated by the expected increase in consumption, which induces producers to raise the price. The demand effect, however, is not strong enough to reverse the reaction of price setters to more precise public signals.

4.6 Discussion

More precise public information has two main effects: first it moves, on average, the aggregate equilibrium allocation closer to the first best allocation, by increasing the information available to price setters. This is, of course, because the only aggregate shock hitting the economy is productivity, and this shock causes efficient fluctuations in equilibrium. The second effect is to decrease the response of the economy to private signals: price-setters rely less on their own productivity to forecast aggregate activity, and rely more on the public signal. This adds noise and non-fundamental fluctuations to the economy.

In the model without any exogenous source of price stickiness, it is well known that the final effect on welfare depends on how strongly individual price-setters value coordination,
compared to society (Angeletos and Pavan [2007], Angeletos et al. [2011]). In this model, households prefer to smooth consumption across varieties, but this cross-sectional smoothing is hampered by the fact that price-setters use private information to forecast aggregate activity.

The conventional wisdom dictates that the welfare properties of the economy with price stickiness are well approximated by the welfare properties of the flexible-price economy. Once again, the conventional wisdom is wrong. The reason is that price stickiness adds a time series component to welfare. In the context of a simple New Keynesian model with Calvo price stickiness, there is additional price dispersion due to the fact that some producers cannot update their price. Since, in equilibrium, price-setters respond more strongly to more precise public signals, prices tend to respond more strongly to noise shocks. This increases the dispersion between producers that are able to adjust and the ones that cannot, and this is detrimental to welfare. In the case of price stickiness as in Rotemberg, the quadratic adjustment cost itself is the new time series component of welfare. Stronger price adjustment due to more precise public information has a direct effect on the adjustment cost, hurting welfare.

The time series component of price dispersion/adjustment cost is summarized by the variance of the inflation rate. Under the forms of price stickiness considered, the fact that inflation becomes more volatile with more precise public information is detrimental to welfare. As in any New Keynesian model, inflation is determined by present and future expected marginal costs (i.e., the utility cost of producing an additional unit). In this model, the marginal cost is inversely proportional to productivity. Inflation becomes more volatile with more precise public information about aggregate productivity because the only persistent variable affecting marginal cost is aggregate productivity itself. Any news about today’s productivity has a direct and strong effect on present and future expected marginal cost, directly hitting inflation. Additional noise contained in this news increases the volatility of the inflation rate.

5 A simple model with physical capital

In this section I introduce physical capital in the model. Investment and endogenous capital accumulation are an essential part of modern macroeconomic models, but they have been mostly neglected in the literature studying the social value of information. The introduction of physical capital brings the analysis closer to the DSGE paradigm (Christiano et al. [2005], Smets and Wouters [2007]), and allows to quantify the changes in welfare induced by more or less precise public information using a more realistic framework.
5.1 The log-linearized model with capital

The economy is identical to the one presented in Section 2, except for the fact that there is an additional production factor, physical capital. I assume that the production technology is given by

\[ Y_{i,t} = \alpha^{1/\alpha} A_{i,t} N_{i,t}^{1-\frac{1}{\alpha}} K_{i,t}^{\frac{1}{\alpha}}, \]

where \( K_{i,t} \) denotes the stock of capital used by producer \( i \). Market clearing imposes

\[ \int_0^1 K_{i,t} di = K_{t-1}, \]

where \( K_{t-1} \) is the stock of installed capital in the economy.

The timing of events is as follows: at the beginning of each period, producer \( i \) chooses its optimal price level, \( P_{i,t} \), if allowed to do so. As before, producers commit themselves to produce as much as it is demanded at that price. After the price is set, they satisfy demand choosing the optimal combination of labor and capital. The capital stock is owned by the households. Households pool the capital together and rent it at a competitive price to the producers. Renting of capital, however, occurs after the intermediate price has been fixed, and the information contained in the rental price of capital is not used by the producers.

In the production stage, firms minimize the cost subject to the demand received at the price \( P_{i,t} \). Given the Cobb-Douglas technology, it follows that the real marginal cost faced by producer \( i \) is, after a log-linear approximation, given by

\[ mc_{i,t} = \frac{1}{\alpha} w_{i,t} + \left(1 - \frac{1}{\alpha}\right) r_t^k - a_{i,t}, \]

where \( w_{i,t} = \sigma c_{i,t} + \eta n_{i,t} \) is the marginal rate of substitution between labor effort and consumption and \( r_t^k \) is the rental price of capital.

From the first-order condition of each firm, it can be shown that the real rental price of capital satisfies

\[ r_t^k = mc_{i,t} + y_{i,t} - k_{i,t} = mc_t + y_t - k_{t-1}, \]

where market clearing imposes \( y_t = \int_0^1 y_{i,t} di \) and \( k_{t-1} = \int_0^1 k_{i,t} di \), and we define the aggregate (cross-sectional average) real marginal cost as \( mc_t = \int_0^1 mc_{i,t} di \).

After some algebra, it can be shown that

\[ mc_{i,t} - mc_t = \frac{-\eta (y_{i,t} - y_t) + (1 + \eta) \alpha (a_{i,t} - a_t)}{-\eta + \alpha (1 + \eta)}, \]

where the aggregate real marginal cost satisfies

\[ mc_t = \sigma c_t - y_t + (1 + \eta) \alpha (y_t - a_t) + (1 + \eta) (1 - \alpha) k_{t-1}. \]
As before, producer $i$ finds it optimal to target the price

$$p^*_{i,t} = p_t + mc_{i,t}.$$ 

If the economy faces the Calvo price stickiness and the producer is allowed to change the price, she will choose

$$p^\text{adj}_{i,t} = (1 - \beta \nu) \mathbb{E} \left[ \sum_{j=0}^{\infty} (\beta \nu)^j p^*_{i,t+j} | I_{i,t} \right].$$ 

The budget constraint of the households is modified to allow for capital accumulation,

$$P_t (C_{i,t} + K_{i,t} - (1 - \delta) K_{i,t-1}) + B_{i,t} = (1 + T^*) P_{i,t} Y_{i,t} + B_{i,t-1} R_{t-1} + X_t,$$

where $\delta \in [0, 1]$ is the depreciation rate.

Since households are able to perfectly diversify all idiosyncratic risk, in equilibrium they hold the same stock of physical capital. The return to capital is determined by the average marginal product of capital, and the optimal capital stock is given by the usual Euler equation, which reads, in its log-linear version,

$$-\sigma c_t = \mathbb{E}_t \left[ -\sigma c_{t+1} + \beta r^{k}_{t+1} \right],$$

with

$$r^{k}_t = mc_t + y_t - k_{t-1}.$$ 

This completes the characterization of the model with physical capital.

### 5.2 Welfare criterion

The addition of physical capital transforms our simple static economy into a truly dynamic economy. The welfare loss approximation found in Proposition 2 is no longer valid. Following Benigno and Woodford [2012], it is possible to find a quadratic approximation of the discounted sum of the expected utility, $W_t$, in an economy subject to backward looking technological and resource constraints. This approximation has the advantage that it does not depend on any linear term, making it possible to correctly rank different linear decision rules using a purely quadratic objective.

The approximation takes the form

$$W_{t_0} = \frac{1}{2} E_{t_0} \sum_{t=t_0}^{\infty} \beta^{t-t_0} \left[ \tilde{y}_t' Q \cdot \tilde{y}_t + 2 \tilde{y}_t' R \tilde{y}_{t-1} + 2 \tilde{y}_t' B (L) \epsilon_{t+1} \right] + t.i.p + \ldots,$$

where $t.i.p.$ stands for “terms independent of policy”, $\tilde{y}_t$ is a vector containing endogenous...
variables,
\[ \tilde{y}_t = \left[ c_t \quad k_t \quad \{k_{i,t}\}_{i \in [0,1]} \quad \{n_{i,t}\}_{i \in [0,1]} \right]',
and \( \varepsilon_t \) is a vector containing exogenous shocks,
\[ \varepsilon_t = \left[ \{a_{i,t}\}_{i \in [0,1]} \right]'. \]

The polynomial in the lag operator, \( B(L) \), is of order one, and it is defined, together with the matrices \( Q \) and \( R \), in Benigno and Woodford [2012]. After a considerable amount of algebra, the following result follows.

**Proposition 3.** The expected aggregate welfare can be approximated as
\[ W = \frac{1}{2} E_0 \left[ \sum_{t=0}^{\infty} \beta^t \hat{W}_t \right], \]
where
\[
\hat{W}_t = -\sigma C^{1-\sigma} c_t^2 - \frac{Y (1 - \frac{1}{\alpha})}{C^{\sigma}} \int_0^1 (k_{i,t} - k_{t-1})^2 \, di - \frac{1}{\alpha} Y C^{-\sigma} (1 + \eta) \int_0^1 (n_{i,t} - n_t)^2 \, di \\
+ \frac{Y (\theta - 1)}{C^{\sigma \theta}} \int_0^1 (y_{i,t} - y_t)^2 \, di + \frac{Y}{C^{\sigma} \theta} \hat{y}_t^2 - \frac{Y (1 - \frac{1}{\alpha})}{C^{\sigma}} k_{t-1}^2 - \frac{1}{\alpha} Y C^{-\sigma} (1 + \eta) n_t^2.
\]

With this welfare criterion, we can rank the equilibrium outcomes attained under alternative disclosure policies.

### 5.3 Welfare and volatility

Figure 4 presents the standard deviation of consumption, inflation and the interest rate as a function of the precision of the public signal, for the economy subject to the Calvo price rigidity. As in the model without capital, the volatility of all variables increases with more precise information. It is interesting to note that the level of the volatility of all variables is higher in the economy with capital than in the economy without capital. The reason is that the presence of an additional choice variable increases the ex-ante variance of output, because now the capital stock, that before was fixed and constant, is now free to respond to the aggregate shocks that hit the economy. The additional time series volatility of output is reflected in consumption, inflation and the nominal interest rate. The qualitative behavior of volatility to the precision of disclosure, however, remains unchanged when the price rigidity is active.

Figure 5 shows the steady-state consumption equivalent change in the welfare loss, with price stickiness (solid line) and without price stickiness (dashed line). The change is measured
Baseline calibration. Depreciation rate $\delta = 0.024$.

with respect to the minimum welfare loss. As in 4, when prices can be adjusted freely, the welfare loss is minimized under full disclosure. Under the baseline degree of price stickiness, however, the welfare loss is instead minimized under no disclosure. Thus, the qualitative implications of the model do not change with the addition of physical capital. The quantitative results, however, are significantly different. The effects of disclosure on welfare are one order of magnitude larger in the economy with capital than in the economy without it.

For each level of precision of the public signal, $\tau_v$, Figure 5 indicates what is the corresponding permanent change in annual steady-state consumption that would keep the households indifferent between $\tau_v$ and the stationary economy that minimizes the loss. Under the Calvo price stickiness, the loss in welfare from more disclosure is modest but significant. Moving from full disclosure to no disclosure at all is equivalent to a permanent increase in annual steady-state consumption of 0.24%. Equivalently, consumers lose 24 basis points of the steady-state level of consumption when the central bank fully discloses its private information. For an intermediate level of disclosure, $\tau_v = (0.009)^{-2}$, the welfare loss corresponds to 10 basis points.

The annual consumption equivalent loss of $\sim 0.25\%$ is economically significant. A household consuming on average $50,000$ a year is willing to pay up to $125$ every year to live in an economy with no disclosure and lower volatility. On the other hand, according to Lucas [1987], the household would be willing to pay only $10$ to eliminate all fluctuations associated with
Baseline calibration. Depreciation rate $\delta = 0.024$.

Finally, if the economy is not subject to the Calvo price stickiness, then more precise disclosure generates a welfare gain. Moving from no disclosure to full disclosure is equivalent to a permanent increase in annual steady-state consumption of 0.35%.

## 6 Conclusions

In this paper I study the relation between disclosure of information by the central bank and social welfare in the context of a simple New Keynesian model. By moving towards the DSGE paradigm, I bring the analysis closer to the type of models that are extensively used to address monetary policy questions and to perform quantitative welfare analysis. Two important ingredients of this framework are price stickiness and capital accumulation. I study the effect of each feature on the social value of information.

This paper illustrates a mechanism through which the disclosure of the central bank’s private information can be harmful for welfare, when there is price stickiness as in Calvo [1983]. When receiving more precise disclosures, the producers that can adjust their price respond more strongly to the public signals. Since a fraction of producers cannot adjust the price every period, by definition they don’t respond to current signals. This introduces

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1 The welfare cost of the business cycle is approximately $\frac{1}{2} \sigma Var[c_t]$, and in annualized terms, using a quarterly variance of $Var[c_t] = 0.007^2$, it amounts to 0.02%. This is one order of magnitude less than the welfare cost of disclosure.
additional cross-sectional price dispersion, which hurts welfare if the price stickiness is strong enough. If the price stickiness arises because of quadratic adjustment costs, as in Rotemberg [1982], disclosure is detrimental to welfare because, by adjusting prices more, producers incur higher adjustment costs.

From a theoretical point of view, the simple mechanism identified in this paper is potentially present in any model of asynchronous, strategic choice under imperfect information. The fact that some agents are able to respond and adjust their actions to current shocks and other agents can't generates additional cross sectional dispersion. More precise information increases the strength of the response of the agents that can adjust to the more precise signals, increasing dispersion. If the cross sectional dispersion of actions is detrimental to welfare, then more precise information can be detrimental to welfare as well. A similar conclusion holds for quadratic adjustment costs. A stronger adjustment due to more precise public signals generates a larger adjustment cost.

Then, I study the effect of adding physical capital to the model. The purpose of this exercise is to quantify the gains/losses derived from more precise disclosure under a framework that is better suited for quantitative welfare analysis. Physical capital increases the effects of information changes on welfare. Moving from no disclosure at all to full disclosure is equivalent to a permanent increase in the annual steady-state consumption level of 0.35%. However, when prices are sticky, disclosure generates a welfare loss of 0.24% in annual consumption. The policy implications are clear: more disclosure about shocks that cause efficient fluctuations in equilibrium is not socially desirable if price stickiness is strong enough.

Finally, this paper also serves as a warning to the literature of social value of information. The lessons learned from simple, static micro-founded models may fail to hold in models that incorporate dynamic features, as price stickiness and capital accumulation, which are closer to the DSGE paradigm.

References


A Appendix

A.1 Rational Expectations Equilibrium

In this section, I find the unique symmetric stationary rational expectations linear equilibrium, taking the Taylor rule and the precision of public signals as given, for the log-linearized version of the model.

To find the linear equilibrium, I follow a “guess and verify” approach. I assume that the optimal price, $p_{t,t}^{adj}$, follows the linear rule

$$p_{t,t}^{adj} = p_{t-1} + \gamma_a a_{t-1} + \gamma_k k_{t-1} + \gamma_\xi (a_{i,t} - \rho a_{t-1}) + \gamma_z (z_t - \rho a_{t-1}),$$

that consumption satisfies

$$c_t = c_a a_{t-1} + c_k k_{t-1} + c_\mu \mu_t + c_\epsilon \epsilon_t + c_v v_t,$$

and that capital follows

$$k_t = k_a a_{t-1} + k_k k_{t-1} + k_\mu \mu_t + k_\epsilon \epsilon_t + k_v v_t.$$

Then, I solve the optimization problems of the consumer and the intermediate producers, and verify that the optimal actions are linear functions, confirming the guess.

A.1.1 Consumption

First, I verify that the linear rule for consumption is optimal for the household, given the guess for the aggregate price. The Euler condition reads

$$c_t = \frac{1}{\sigma} (-r_t + E_t [p_{t+1} - p_t]) + E_t [c_{t+1}],$$

and it determines consumption in equilibrium.

First, consider the aggregate price index. A fraction $\nu$ of producers cannot adjust their price. Since these households are drawn at random, their average price equals $p_{t-1}$. It follows that

$$p_t = \nu p_{t-1} + (1 - \nu) \int p_{t,t}^{adj} di = p_{t-1} + (1 - \nu) (\gamma_a a_{t-1} + \gamma_k k_{t-1} + \gamma_\mu \mu_t + \gamma_z (z_t - \rho a_{t-1})), $$

where the integral is taken over the set of producers that adjust prices in period $t$.

Using the expression for $p_{t+1}$ from the linear price rule, and the expression for $c_{t+1}$ from...
the linear consumption rule, it follows that

\[ E_t [p_{t+1} - p_t] = (1 - \nu) (\gamma_a a_t + \gamma_k k_t), \]
\[ E_t [c_{t+1}] = c_a a_t + c_k k_t. \]

Substituting the aggregate price in the interest rate rule, it follows that

\[ r_t = \phi (1 - \nu) (\gamma_a a_{t-1} + \gamma_k k_{t-1} + \gamma_i E_t[I_{CB,t}] + \gamma_z (z_t - \rho a_{t-1})), \]

where

\[ E_t[I_{CB,t}] = \frac{\tau_\varepsilon}{\tau_a + \tau_\varepsilon} (s_t - \rho a_{t-1}). \]

Then, the Euler equation becomes

\[ c_t = \frac{1}{\sigma} (-r_t + E_t [p_{t+1} - p_t]) + E_t [c_{t+1}], \]
\[ = -\frac{\phi (1 - \nu)}{\sigma} (\gamma_a a_{t-1} + \gamma_k k_{t-1} + \gamma_i E_t[I_{CB,t}] + \gamma_z (z_t - \rho a_{t-1})) + c_a a_t + c_k k_t + \frac{1 - \nu}{\sigma} (\gamma_a a_t + \gamma_k k_t). \]

This expression verifies the guess and proves the following Lemma.

**Lemma.** Assume that the aggregate price follows the linear rule

\[ p_t = p_{t-1} + (1 - \nu) (\gamma_a a_{t-1} + \gamma_k k_{t-1} + \gamma_i I_{t} + \gamma_z (z_t - \rho a_{t-1})) \]

and that

\[ k_t = k_a a_{t-1} + k_k k_{t-1} + k_\mu \mu_t + k_\varepsilon \varepsilon_t + k_\nu \nu_t. \]

Then, optimal consumption follows the linear rule

\[ c_t = c_a a_{t-1} + c_k k_{t-1} + c_\mu \mu_t + c_\varepsilon \varepsilon_t + c_\nu \nu_t, \]

where

\[ c_a = -\frac{(1 - \nu) (\gamma_k k_a (\phi - 1) + \gamma_a (\phi - \rho) (1 - k_k))}{\sigma (1 - k_k) (1 - \rho)}, \]
\[ c_k = -\frac{\gamma_k (k_k - \phi) (1 - \nu)}{\sigma (1 - k_k)}, \]
\[ c_\mu = -\frac{(1 - \nu) (\phi - 1) (\gamma_a (1 - k_k) + \gamma_k (k_a + (k_\mu - k_\varepsilon) (1 - \rho))))}{\sigma (1 - k_k) (1 - \rho)} + c_\varepsilon, \]
\[ c_\varepsilon = -\frac{1 - \nu}{\sigma (1 - k_k)} \left( \gamma_k k_\varepsilon (\phi - 1) + \left( \gamma_z + \frac{\tau_\varepsilon}{\tau_a + \tau_\varepsilon} \gamma_\varepsilon \right) \phi (1 - k_k) \right), \]
\[ c_\nu = \frac{1 - \nu}{\sigma (1 - k_k)} (\gamma_k k_\nu - \phi (\gamma_z (1 - k_k) + \gamma_k k_\nu)). \]
A.1.2 Capital

Capital accumulation satisfies the Euler equation

\[-\sigma c_t = E_t \left[ -\sigma c_{t+1} + \beta \left( 1 - \frac{1}{\alpha} \right) \left( \frac{K}{Y} \right)^{-1} (y_{t+1} - k_t) \right],\]

where aggregate output is

\[y_t = \frac{C}{Y} c_t + \frac{K}{Y} (k_t - (1 - \delta) k_{t-1}),\]

and

\[\frac{K}{Y} = \beta \left( \left( 1 - \frac{1}{\alpha} \right) + 1 - \delta \right),\]
\[\frac{C}{Y} = 1 - \delta \frac{K}{Y},\]

are steady-state ratios.

From the linear guess,

\[E_t k_{t+1} = k_a a_t + k_k k_t,\]
\[E_t y_{t+1} = \frac{C}{Y} (c_a a_t + c_k k_t) + \frac{K}{Y} (k_a a_t + (k_k - (1 - \delta)) k_t).\]

Then, the capital Euler equation becomes

\[-\sigma c_t = -\sigma c_a a_t - \sigma c_k k_t + \beta \left( 1 - \frac{1}{\alpha} \right) \left( \frac{K}{Y} \right)^{-1} \left( \left( \frac{C}{Y} c_a + \frac{K}{Y} k_a \right) a_t + \left( \frac{C}{Y} c_k + \frac{K}{Y} (k_k - (1 - \delta)) - 1 \right) k_t \right),\]

and after substituting in for \(c_t, a_t\), it is verified that \(k_t\) is a linear function of \(a_{t-1}, k_{t-1}, \mu_t, \varepsilon_t\) and \(v_t\). In equilibrium, the coefficients from the linear guess must be equal to the coefficients obtained from the linear Euler equation.

**Lemma.** In equilibrium, the following equations must be satisfied:

\[k_a = \frac{-\sigma c_a (1 - \rho) - \beta \left( 1 - \frac{1}{\alpha} \right) \left( \frac{K}{Y} \right)^{-1} \frac{C}{Y} c_a \beta}{-\sigma c_k + \beta \left( 1 - \frac{1}{\alpha} \right) \left( \frac{K}{Y} \right)^{-1} \left( \frac{K}{Y} (k_k + \rho + \delta - 1) - 1 \right) \frac{C}{Y} c_k},\]
\[k_\mu = \frac{C}{Y} \beta c_a (\alpha - 1) + \frac{C}{Y} \beta (\alpha - 1) c_k + \frac{K}{Y} \beta (1 - \delta - k_k) (\alpha - 1) + \frac{C}{Y} c_k \alpha c_k \sigma}{(\alpha - 1) \beta - \frac{C}{Y} \beta (\alpha - 1) c_k + \frac{K}{Y} \beta (1 - \delta - k_k) (\alpha - 1) + \frac{C}{Y} c_k \alpha c_k \sigma},\]
\[k_\varepsilon = \frac{K}{Y} \alpha c_e}{(\alpha - 1) \beta - \frac{C}{Y} \beta (\alpha - 1) c_k + \frac{K}{Y} \beta (1 - \delta - k_k) (\alpha - 1) + \frac{C}{Y} c_k \alpha c_k \sigma},\]
\[k_v = \frac{K}{Y} \alpha c_v}{(\alpha - 1) \beta - \frac{C}{Y} \beta (\alpha - 1) c_k + \frac{K}{Y} \beta (1 - \delta - k_k) (\alpha - 1) + \frac{C}{Y} c_k \alpha c_k \sigma},\]
and \( k_k \) must solve

\[
c_k \sigma - c_k k_k \sigma + \beta \left( 1 - \frac{1}{\alpha} \right) \left( \frac{K}{Y} \right)^{-1} \left( \frac{K}{Y} \left( k_k^2 + k_k (\delta - 1) \right) - k_k + \frac{C}{Y} c_k k_k \right) = 0.
\]

The solution for \( k_k \) is picked such that capital is stationary (\(|k_k| < 1\)).

### A.1.3 Aggregate Price

The optimal price is

\[
p_{i,t}^{adj} = (1 - \beta \nu) E \left[ \sum_{j=0}^{\infty} (\beta \nu)^j p_{i,t+j}^* |I_{i,t} \right],
\]

where the target price is

\[
p_{i,t}^* = p_t + (1 - r) \left( y_t - a_{i,t} + \frac{\sigma c_{i,t} - y_t}{\alpha (1 + \eta)} - \left( 1 - \frac{1}{\alpha} \right) k_{t-1} \right).
\]

Note that the optimal price satisfies the recursive equation

\[
p_{i,t}^{adj} = E \left[ (1 - \beta \nu) p_{i,t}^* + \beta \nu p_{i,t+1}^{adj} |I_{i,t} \right],
\]

where \( p_{i,t+1}^{adj} = (1 - \beta \nu) E \left[ \sum_{j=0}^{\infty} (\beta \nu)^j p_{i,t+1+j}^* |I_{i,t+1} \right] \) is the price that the producer would set if it could adjust it in period \( t + 1 \).

It follows from the linear guess for \( p_{i,t}^{adj} \) that

\[
E \left[ p_{i,t+1}^{adj} |I_{i,t} \right] = E \left[ p_t + \gamma_a a_t + \gamma_k k_t |I_{i,t} \right],
\]

and then

\[
p_{i,t}^{adj} = E \left[ p_t + (1 - \beta \nu) (1 - r) \left( y_t - a_{i,t} + \frac{\sigma c_{i,t} - y_t}{\delta (1 + \eta)} - \left( 1 - \frac{1}{\alpha} \right) k_{t-1} \right) + \beta \nu (\gamma_a a_t + \gamma_k k_t) |I_{i,t} \right].
\]

Noting that in equilibrium \( y_t = \frac{C}{Y} c_t + \frac{K}{Y} (k_t - (1 - \delta) k_{t-1}) \), substituting the guess for \( c_t, k_t \), the aggregate price level \( p_t \) and the process \( a_t \), and taking expectations over the shocks \( \mu_t, \nu_t \) and \( \varepsilon_t \), it follows that \( p_{i,t}^{adj} \) is a linear function of \( p_{t-1}, a_{t-1}, k_{t-1}, a_{i,t} - \rho a_{t-1} \) and \( z_t - \rho a_{t-1} \).

This confirms the guess about \( p_{i,t}^{adj} \), and gives expressions for the coefficients \( \gamma_a, \gamma_k, \gamma \) and

\[
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\]
\(\gamma_z\), as functions of parameters of the model. In particular, \(\gamma_a\) and \(\gamma_k\) satisfy

\[
\begin{align*}
\gamma_a &= (1 - \beta \nu) (1 - r) \left( \rho - \frac{C}{\nu} c_a - \frac{K}{r} k_a + \frac{C}{\nu} c_a - \frac{K}{\nu} c_a - c_a \sigma - \beta \gamma_k k_a \nu \right), \\
\gamma_k &= \frac{(\beta - 1) (r - 1) \left( \frac{C}{\nu} c_k - I_k \left( 1 - \frac{1}{\alpha} \right) + \frac{K}{r} (\delta + k_k - 1) - \frac{C}{\nu} c_k - c_k \sigma + \frac{K}{\nu} (\delta + k_k - 1) \right)}{\nu - \beta k_k \nu},
\end{align*}
\]

where \(I_k\) is an indicator, equal to one if capital is present in the model, and equal to zero if there is no endogenous capital.

The expressions for \(c_a\), \(k_a\), \(\gamma_a\), \(c_k\), \(k_k\) and \(\gamma_k\) depend only on each other, and not on the variance or precision of any shock hitting the economy. In particular, they are independent from the precision of the public signal, \(\tau_v\).

Note also that \(c_\mu - c_\varepsilon\) and \(k_\mu - k_\varepsilon\) are independent from \(\tau_v\) as well.

### A.1.4 The model without capital

The equilibrium for the model without capital can be obtained by setting \(k_a = k_k = k_\mu = k_\varepsilon = k_v = 0\), \(C = 1\), \(K = 0\) and \(I_k = 0\).