On Fed Watching and Central Bank Transparency*

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Abstract: In this paper, I examine central bank transparency in two different general equilibrium settings. A transparent central bank eliminates any uncertainty about future money growth. Agents can expend resources to process messages about future money growth, which is labelled fed watching. So transparency is equivalent to a case in which a private agent processes all of the central bank's messages and correctly infers what the future money growth rate will be. In both settings, conditions are derived in which a proper subset of messages are processed. In one setting, this outcome reflects the central bank's efforts to be secretive. In the other, the central bank is opaque because the absence of transparency is the key to letting a benevolent central bank follow a state-contingent rule.

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Consider the legions of economists whose sole function it is to interpret U.S. Federal Reserve Chairman Alan Greenspan's every twist and turn of phrase so as to divine which way the monetary winds are blowing."
Caroline A. Baum, The Last Word p.64

1 Introduction

The quote serves as an insightful, albeit casual, piece of empiricism. Two important "findings" are stressed. One is that resources are expended trying to infer what monetary policy action will be taken. The other is that the central bank makes statements that might yield some insight into its future plans, but the messages are not typically transparent.

Why are central banks not totally transparent about their future actions? Goodfriend (1986) laid out the case for transparency, arguing point-by-point against the Federal Reserve's case for withholding the FOMC's deliberations. Grossman and Stiglitz (1980), Dotsey (1987), and Tabellini (1987) develop models in which the costs of central-bank secrecy are identified. In this literature, agents must forecast interest rates and the objective is to maximize forecast-error accuracy. Secrecy, therefore, raises the costs because forecasts are less accurate. Rudin (1988) extends this literature to consider a case in which some agents can learn about future actions by fed watching.[1] In Rudin's model the quantity of fed watching is exogenously determined. Depending on the fraction of agents who fed watch, Rudin considers a case in which the central bank is less secretive, showing that the non-fed watchers may become less accurate forecasters.[2]

[1] Balke and Haslag (1991, 1992) also study models in which agent's can expend resources to mitigate uncertainty.

[2] Note further that in Rudin's setup, fed watching lets informed agents know the money supply shock. Hence, if each agent was a fed watcher, there would be no central bank secrecy. Cosimano and Van Huyck (1993) investigate a case in which banks try to extract noisy signals from the FOMC's

Cukierman and Meltzer (1986) develop notions of central bank transparency.[3] They derive conditions in which a central bankers uses imperfect monetary control to mask their intentions. In other words, Cukierman and Meltzer's central bank combine the absence of transparency with control errors to meet its objective at the lowest possible reputation cost. More recently, Faust and Svensson (1999) extend the Cukierman-Meltzer setup, distinguishing between transparency and control error. In doing so, the central bank chooses the pair that maximizes its objective function. They find that central banks would choose to be opaque.

The purpose of this paper is account for both fed watching and central bank transparency. It is related to the earlier literature in the sense that I am interested in deriving conditions in which the central bank will not be transparent. There are two modifications. First, I examine these activities in a simple general equilibrium model. An obvious advantage to this approach is that it is straightforward to do welfare analysis. Indeed, welfare is the basis for comparing different polices. Second, transparency is characterized how costly it is for private agents to draw inference about future central bank actions from the central bank speeches. Cukierman and Meltzer permit the central bank to make a single announcement. Faust and Svensson characterize transparency in terms of the quality of the announcement. Effectively, the announcement is higher quality when the distribution around that announcement has a lower variance. Because the central bank makes a sequence of statements regarding it intentions about monetary policy, transparency corresponds roughly to what it costs to make sense out of the central bank statements.

Communication plays a big role in this setup. More specifically, I am interested in the communication between the central bank and agents. Communication, however, only becomes valuable to the agent when it is processed. So, the central bank's state-

policy directive. In their setup, the directive is deemed secretive because it is released after the directive is no longer relevant.

[3] Their model builds on the policy-game models developed by Kydland and Prescott (1977) and Barro and Gordon (1983a,b) for

ments are distributed freely, but it is costly to people to translate these statements into something useable about the central bank's future actions. Here, communications are continuous with the unit of measurement labeled a message. There are a finite number of messages that constitute the central bank's communication and transparency exists when private agents process all of the messages. Agents must expend resources–fed watch–to process these messages, which means that they forego consumption. By processing all the messages, the central bank is transparent, which corresponds to a case in which there is no uncertainty about future money growth rates.[4]

In this economy, money is nonneutral. Each period, N agents are born and their preferences are identical. The agent is finite lived and holds fiat money to satisfy a portfolio restriction. Because of the reserve requirement, the gross real return to saving depends on the realized money growth rate. In a setup in which the agent lives two periods, all the risk arises in old age because the gross real return to fiat money is unknown at the time the agent must make the consumption-saving decision. Agents have concave utility functions, explaining why uncertain future money growth matters to one's expected lifetime welfare.[5]

In addition to the consumption-saving decision, the agent decides how to allocate resources between consumption when young and fed watching. Obviously, fed watching means that the agent foregoes some consumption. The marginal gain to the agent comes in the form of transforming the distribution of future money growth rates. In other words, I assume there exists a technology such that fed watching is transformed such that the agent's expected utility is greater. In short, the agent prefers the distribution with greater fed watching than the one without. The question then is whether it is worth it to fed watch.

[4]Here, I use the term transparency analogously to the notion of a fully revealing equilibrium positied by Milgrom (1981).

[5]Sandmo (1970) looks at the effect of uncertainty on consumption-saving decisions in partial equilibrium.

Fed watching consists of acquiring elements from the set of central-bank messages. The costs arise because the agent expends resources to process each message. So, I assume there is a nonnegative fee, which is the same for each message processed, that is interpreted as the quantity of consumption good used to transform the message into a change in the distribution function. For instance, if the agent were to process all the messages at date t, the processing technology yields a degenerate distribution with probability mass centered on the realized date $t+1$ money growth rate. One can interpret the fee as being a measure of how opaque the central bank's messages are.

In this paper, I derive two sets of conditions. First, under what conditions will agent choose to pay some positive processing fee? Once these conditions are obtained, it is straightforward to show the welfare costs associated with an opaque central bank. In addition to establishing conditions in which fed watching occurs in equilibrium, central-bank transparency represents a benchmark for other welfare comparisons.

Second, under what conditions would a central bank wish to be opaque? I offer two possible explanation for why a central bank might choose opaqueness. One emphasizes the role of differential objective functions. For instance, the notion that a central bank maximizes a social objective function that differs from the private agents can account for an equilibrium is which the central bank is opaque. The other explanation, however, emphasizes the flexibility that opaqueness offers the central bank. Indeed, I study models in which it is natural to interpret opaqueness as being consistent with interest-rate targeting and transparency is consistent with money growth targeting. As such, opaqueness permits the central bank to respond to external shocks that actually result in welfare gains.

The remainder of the paper is organized as follows. The economic environment is described in Section 2 along with the definition and characterization of the rational-expectations equilibrium. Section 3 presents a more concrete example of fed watching and the transformation to the distribution function depicting future money growth. Section 4 presents two propositions pertaining to the effect that changes in the processing fee have on the agent's welfare and on economic activity. In Section 5, the environment is modified to allow the central bank to choose the processing fee. Section 6 examines the central bank's decision regarding the processing fee in an environment with uncertain returns to capital. A brief discussion of the results is offered in Section 7.

2 The Model

2.1 The Environment

The model is a modified version of Cass and Yaari's (1966) overlapping generations economy. Time is indexed by $t = 1, 2, ...$ In each period, N two-period lived agents are born. An agent born at date t maximizes the expected value of lifetime utility, $\bar{W} = U(c_{1t}) + \ E \ V(c_{2t+1})$, where c_i denotes the units of the consumption in agent's i^{th} period of life. The functions, U, V are thrice-continuously differentiable, strictly concave and strictly increasing in units of the consumption good with $\lim_{c_1 \to 0} U'(.)$, and $\lim_{c_2 \to 0} V'(.) = \infty$.

Each agent born at date $t \geq 1$ is endowed with one unit of productive time when young and nothing when old. The unit of time is supplied inelastically to the market, producing y units of the consumption good. The consumption good spoils at the end of the period. At date $t = 1$, there are N agents who live for only one period. Referred to as the "initial old," these agents do not have productive time. The utility of the initial old is represented by $V(c_{21})$.

Because the agent values consumption when young and when old, the problem is to use first-period income to finance second-period consumption. In this economy, there are three assets. One is capital. Consumption goods can be costlessly transformed into capital. Capital goods acquired at date t are transformed into units of the consumption good at date $t+1$ according to the function, $f(k_t)$. The function has the following properties: $f'(.) > 0, f''(.) < 0, f(0) = 0, \lim_{k \to 0} f'(.) = \infty$, and $\lim_{k \to \infty} f'(.) = 0$. All capital is completely depreciated by production process. The second asset is government bonds. A young agent can purchase b_t dollars worth of government bonds at date t, receiving $R_{t+1}b_t$ dollars at date $t+1$, with $R > 1$. Let v_t denote the quantity of the consumption good that is traded for one dollar. Thus, a young agent trades $v_t b_t$ units of the consumption good when young, receiving $v_{t+1}R_{t+1}b_t$ units of the consumption good when old. The third asset is fiat money. A young agent trades units of the consumption good for $v_t m_t$ worth of fiat money at date t. One period later, the agent can purchase $v_{t+1}m_t$ units of the consumption good. It follows that $s_t = k_t + v_t b_t + v_t m_t$.

Fiat money does not pay interest and government bonds do. Let v denote the value of fiat money (the number of goods that can be acquired with one unit of money). Because money is rate-of-return dominated, v will be greater than zero if and only if there is some reason for the agent to hold it. Following Bryant and Wallace (1980), I apply a legal restriction, assuming that some fraction of a young agent's saving must be in the form of fiat money. Formally, let $v_t m_t = \lambda s_t$. In addition, to pin down the distribution of the agent's savings, I assume $v_t b_t = \delta s_t$.[6] Here, $0 \leq \lambda, \delta \leq 1$ and $\lambda + \delta \leq 1$. Because government paper–bonds and fiat money– cannot exceed the quantity of the agent's savings, there is an implicit nonnegativity constraint on the capital stock.

Each member of the initial-old generation is endowed with s_0 units of the consumption goods. The initial old's savings consist of capital, k_0, government bonds and fiat money equal to b_0 and m_0 dollars; in short, $s_0 = k_0 + v_1 b_0 + v_1 m_0$. The utility of the initial old is strictly increasing in the quantity of the consumption good.

[6] Here, δ can be interpreted as a secondary reserve requirement. In this case, an agent will hold some government bonds even though it may be rate of return dominated by capital. Alternatively, suppose the the gross real return on capital and the risk-adjusted gross real return to government bonds are equal. In this interpretation, δ pins down the bond-saving ratio, thus making the agent's portfolio allocation determinate.

The stock of money evolves according to the rule, $m_t = \theta_t m_{t-1}$.[7]

In this economy, uncertainty arises because agents cannot perfectly forecast the growth rate of the money stock. Money growth, denoted θ, can change from period to period; indeed, it is represented as a stochastic process. I assume the process is independently and identically distributed, though including a moving -average term would not materially alter the results in this paper. Money is created and distributed as lump-sum transfer payment to agents when old; that is, $a_t = (\theta_t - 1)v_t m_{t-1}$ dollars are transferred to members of the generations born at date $t-1$. Members of the young generation do not know the realization of θ until date t. The implication is that young agent's do not know the realization of the government's lump-sum transfer and consequently do not know the gross real return to saving when they must make their consumption-saving decision. Thus, uncertainty about the future money growth rate is equivalent to uncertainty about the quantity of second-period resources.

In this paper, the government has three distinct functions: paying its debt, making lump-sum transfer payments, and generating messages. Debt obligations are met by either issuing new debt or through lump-sum tax receipts. The government uses seigniorage to finance its transfer payments.[8]

I assume there are a finite number $(T < \infty)$ of messages and that the messages are ordered and standardized in the sense that each message's marginal impact on the agent's information set is the same and independent of the message.[9] Messages are divisible so that agents can acquire partial messages. Let $\Phi(t) = \{\phi_1(t), \phi_2(t), ..., \phi_T(t)\}$ denote a set of messages that are available. Suppose an agent wishes to acquire date-t messages. It is costless to acquire a message. Costs

[7] Note that I specify the growth rate in per-young-person terms. This is equivalent to specifying things in aggregate terms because the population is constant. Letting population grow according to a fixed rule would not materially change the conclusions drawn in this paper.

[8] See Champ and Freeman (1990) for a description of a government in which there are "dedicated" government budget constraints. Here, dedicated refers to the specification that certain revenues are dedicated to specific types of government expenditures.

[9] See Allen (1989) for description of an economy in which there is costly, differentiated information.

are incurred when the agent processes a message and I assume the messages must be processed sequentially.[10] In processing a message, the agent modifies the distribution of future outcomes. I assume, for simplicity, that each message has a positive marginal product. In other words, a processed message results in a distribution function that is no less preferred to a distribution in which a fewer number of messages are processed. As the reader will see, this is a necessary, but not sufficient assumption to guarantee that an interior quantity of fed watching. I assume that the agent knows the processing technology. So, the agent acquires the message and can determine whether it is worth expending the effort to transform the message into a change in the distribution or not. Clearly, this not imply that the agent will process all of the messages.

The premise here is that fed watching is costly. Hence, I need to describe the processing costs, measured in units of the consumption good, to the watcher. I assume that there is a processing fee such that it takes ρ goods to convert a message into a change in the agent's distribution function. The government does not receive anything from the acquisition of these messages. Thus, the total amount spent on government messages is the product $\rho\omega_t$ where ω_t is the cardinal number of the set of processed messages. A convenient way to think of ω is as follows: suppose that the agent processes messages equal to the set, $A_t = \{\phi_1(t), \phi_2(t), ..., \phi_\epsilon(t)\}$, where $\epsilon \leq T$. Then $\omega = \frac{\epsilon}{T}$. In words, ω is the fraction of the set of messages processed by the agent. As the number of messages processed increases, ω, be definition, increases. For now, I assume that ρ is determined by nature. I will relax this assumption in later sections of the paper.

Formally, the government's budget constraints are represented as

[10] I am attempting to draw a distinction between acquisition and processing that is akin to the difference between reading words and comprehending them. Comprehension takes relatively greater effort.

$$R_t v_t b_{t-1} = v_t b_t + \tau_t \tag{1}$$

$$v_t \left(m_t - m_{t-1}\right) = a_t \tag{2}$$

The agent's problem adds fed watching to the usual consumption-saving decision. I assume that the non-fed watching agent maximizes expected utility conditioned on the information set denoted by Ω_0, where Ω_0 is the information set that is taken as given by the young agent. Note that the information set is stationary over time. By acquiring messages, the agent's information set is represented by $\Omega_t = \Omega_0 \cup A_t$.

What is the payoff to fed watching?. I introduce a technology such that an additional message transforms the conditional distribution function. Let $G(\theta_{t+1}|\Omega_0)$ denote the distribution function for the money growth rate conditional on an agent abstaining from fed watching. The distribution function is twice continuously differentiable, with the first derivative yielding a density function, denoted $g(\theta_{t+1}|\Omega_0)$. The random variable, θ, has nonnegative supports. With $\theta = 0$, fiat money is completely removed from the economy. In contrast, with $\theta = \infty$, the quantity of fiat money is infinitely large, so that with finite savings, the value of fiat money is zero in equilibrium . In other words, the supports of the distribution function correspond to non-monetary economies.

Thus, the young's budget constraint is represented by

$$y \geq c_{1t} + s_t + \rho_t \omega_t \tag{3}$$

and that of the old agents is represented as

$$r_{t+1} s_t + a_{t+1} - \tau \geq c_{2t+1} \tag{4}$$

2.2 Equilibrium

Define a rational expectations competitive equilibrium for this model economy consists of a sequence of functions for agent's allocations–$\{c_{1t}\}, \{c_{2t}\}$ (or $\{d_t\}$), and $\{\Omega_t\}$–prices, $\{\rho_t\}$ and $\{r_t\}$ and policy settings $\{\tau_t\}, \{\theta_t\}, \{b_t\}$, and $\{\lambda_t\}$ such that

(i) agents choose consumption and deposits, taking prices and policy variables as given, to maximize lifetime utility;

(ii) agents choose–$\{\Omega_t\}$–which pins down the conditional probability density function of money growth rates that solves their maximization problem and corresponds to the objective distribution function;

(iii) markets clear and the government budget constraints [equations 1-2] are satisfied.

The maximization problem for the agent born at date t can be expressed as the choice of deposits and messages to maximize $\bar{W}$ subject to equations (3) and (4). Together, the government budget constraints and the market clearing conditions–$v_t b_t = \delta s_t$, $v_t m_t = \gamma s_t$–indicate that, in equilibrium, agents choose a quantity of government bonds and fiat money that is equal to the amount offered by the government.

What is different in this paper is the buying and selling of messages about next period's money growth rate. The intuition is straightforward. For instance, consider a stationary equilibrium for this economy. The money market clearing condition implies that the ex post real return to fiat money is equal to the inverse of the money growth rate. By construction, the gross real return to savings is inversely related to the monetary growth rate. Agents potentially want to buy messages because it reduces uncertainty about the money growth rate.

Consider the program for an agent that maximizes lifetime welfare. More precisely, using the agent's budget constraints, the objective is to choose the level of saving that maximizes expected lifetime utility. The agent's program is,

$$\max_{s_t,\omega_t} \bar{W} = U\left(y - s_t - \rho_t \omega_t\right) + EV\left(r_{t+1}s_t + a_{t+1} - \tau\right) \tag{P1}$$

For now, it is sufficient to note that the agent's uncertainty is with respect to the resources available for second-period income. More specifically, the gross real return to savings is a function money growth rate. Each unit of fiat money acquired at date t, costing v_t units of the consumption good, is worth v_{t+1} units of the consumption good at date $t+1$. Hence, the gross real return to fiat money is $\frac{v_{t+1}}{v_t}$. In a stationary setting, the money market clearing condition implies that $\frac{v_{t+1}}{v_t} = \frac{1}{\theta_{t+1}}$. In addition, it is clear from the government budget constraint that the size of the lump-sum transfer payment is also a function of the money growth rate. The bottom line is that both the gross real return, r, and the lump-sum transfer payment, a, are random variables influenced by the random variable, θ. I denote the relationships as: $r_{t+1} = r\left(\theta_{t+1}\right)$ and $a_{t+1} = a\left(\theta_{t+1}\right)$. Thus, the expected second-period utility is written as

$$EV\left(r_{t+1}s_t + a_{t+1} - \tau\right) = \int_0^\infty V\left[r\left(\theta_{t+1}\right)s_t + a\left(\theta_{t+1}\right) - \tau\right] g\left(\theta_{t+1}|\Omega_t\right) d\theta$$

With this expression, it is straightforward to see that changes in the quantity of goods used to acquire messages affect the agent's second-period utility through a transformation to the density function.

To make the agent's optimizing conditions explicit, the first-order conditions for this program are

$$-U'\left(.\right) + \int_0^\infty V'\left[.\right] r\left(.\right) g\left(.\right) d\theta = 0 \tag{5}$$

and

$$-\rho_t U' + \int_0^\infty V\left[.\right] g'\left(\theta_{t+1}|d\Omega_t\right) d\theta = 0 \tag{6}$$

where $g'\left(.\right)$ denotes the transformed probability density function. In words, $g'\left(.\right)$ characterizes the probability that a particular value of θ is realized when the agent acquires a slightly larger quantity of information.

Equation 5 is the standard Euler equation; an agent chooses the level of saving at which the marginal utility lost by foregoing a little more first-period consumption is equal to the expected marginal utility gained by saving it, receiving an expected gross real return equal to r and consuming it in the second period of life.

Equation 6 is different. The expression says that messages are acquired up to the point at which the agent is indifferent between it and the marginal utility associated with foregoing consumption when young. Equation (6) restricts our attention to a class of transformations to the conditional probability density function such that expected utility is higher with more messages.[11] In particular, we are looking only at messages that are productive in the sense that expected utility is raised. Because messages are standardized, I exclude messages that would result in greater uncertainty. Thus, the class of transformations correspond to those in which these messages yield positive marginal value. Otherwise, we are limited to a corner solution in which there is no fed watching. To satisfy the second-order conditions, note that marginal product of each additional message is diminishing.

Though the economics is fairly straightforward, it is probably useful to make the transformation to expected utility a bit more clear. Suppose there are two distributions corresponding to different levels of fed watching. Let $\Omega_0 + dA$ represent a case in which (an infinitesimally small) quantity of messages is acquired.[12] Accordingly, the two density functions are $g(\theta_{t+1}|\Omega_0 + dA)$ and $g(\theta_{t+1}|\Omega_0)$, respectively. Thus, the change in expected utility is

$$\int_0^\infty V[.]\, g(\theta_{t+1}|\Omega_0 + dA)\, d\theta - \int_0^\infty V[.]\, g(\theta_{t+1}|\Omega_0)\, d\theta$$

Hence, expected utility is computed under two different density functions. To ensure that this expression is positive, I focus on members of the class of information-

[11] See Bertocchi and Wang (1996) for a model economy in which agent's consumption-saving decision is explicit. In their setup, agent's costlessly learns about the technological parameters.

[12] More precisely, the information set $\Omega_0 \subset \Omega_0 + dA$, where dA denotes a marginal change in the quantity of messages processed. Note that ω is increasing with the number of messages processed.

processing technologies characterized by distributions in which a distribution with more intense fed watching (larger ω) stochastically dominates distributions with less intense fed watching (smaller ω). Formally, the distribution function $G(\theta_{t+1}|\Omega_0 + dA)$ stochastically dominates the distribution function $G(\Omega_0)$ for $dA > 0$.[13]

In this paper, I focus on stationary equilibrium. In particular, the key property is $s_t = s_{t+1}$ $\forall t \geq 1$.[14] The gross real return to saving is

$$r_{t+1} = (1 - \delta - \lambda) f'(.) + \delta \frac{R_{t+1}}{\theta_{t+1}} + \lambda \frac{1}{\theta_{t+1}}. \tag{7}$$

Equation 7 indicates that the gross real return to savings is a weighted sum of the three asset returns: capital, government bonds, and fiat money. The weights are the assets shares.

In the next section, I consider a particular member of the class of information-processing technologies. I focus on a case in which the expected rate of money growth is invariant to the level of fed watching. This imposes restrictions on the form of stochastic dominance. Specifically, the distribution $G(\Omega + dA)$ exhibits second-order stochastic dominance in relation to the distribution $G(\Omega)$. For this case, it is possible that the mean value is constant. For the special case in which the mean value of the distribution $G(\Omega + dA)$ is equal to the mean value of the distribution $G(\Omega)$, then $G(\Omega + dA)$ is a mean-preserving contraction of $G(\Omega)$. We will investigate this particular case in more detail in the following section.

3 Gains from fed watching: a concrete example

To make the information payoff more concrete, suppose that a representative young agent pays for a message. Further, let money growth rates have finite, nonnegative supports; that is, $0 \leq \theta_* < \theta^*$ The effect of a change in fed watching is captured as

[13] See Hadar and Russell (1969) for a proof of this result.

[14] For the sake of completeness, the properties of a stationary equilibrium include $c_{1t} = c_{1t+1}$, $c_{2t} = c_{2t+1}$, $k_t = k_{t+1}$, $v_t b_t = v_{t+1} b_{t+1}$, and $v_t m_t = v_{t+1} m_{t+1}$.

a transformation of the random variable, θ. Let $\theta' = w_0 + w_1\theta$, where $w_0 = q\bar{\theta}$ and $w_1 = 1 - q$ and $0 < q < 1$.[15] Here, $\bar{\theta}$ denotes the mean, or expected money growth rate for the density function $g(\theta|\Omega)$. Note that this linear affine transformation of the random variable yields a mean-preserving contraction of conditional density function, or alternatively, θ' dominates θ in the sense of second-order stochastic dominance (hereafter, SSD).

In this setting, q is a weight. As q increases, the effect is equivalent to putting less weight on the values in the tails and more on the mean value. One way to capture the effect of fed watching is let the weight depend on the quantity of messages acquired by the agent. In other words, let $q_t = h(\Omega_t)$. The $h(.)$ function has the following properties: $h(0) = 0$, $h[\Phi(t)] = 1$, $h'(.) > 0, h''(.) < 0$. These properties have the following economic interpretation. If no messages are acquired by private agents, $q = 0$ and the conditional density function for θ' is the same as the conditional density function for θ. If, however, the agent acquires all the messages available, the density function of θ degenerates and the agent knows, with certainty, what next period's money growth rate is. With $h'(.) > 0$, the payoff to acquiring messages is that the conditional distribution for θ' SSD θ. By focusing on a mean-preserving contraction, the idea is that the agents' money-growth-rate forecast is unbiased, with or without message acquisition. Finally, $h''(.) < 0$, asserts that the marginal payoff to message acquisition to the agent is diminishing in Ω.

Now, the link between fed watching and the transformation of the random variable

[15] Alternatively, one can think of the transformation as going the other way; that is,

$$\theta = \theta' + \alpha(\theta' - \bar{\theta}')$$

where $\bar{\theta}'$ dentoes the mean of the distribution function of θ' and $\alpha > 0$. A mean-preserving spread, therefore, requires that $\bar{\theta}' = \bar{\theta}$. Rewrite this expression, solving for θ', obtaining

$$\theta' = \frac{1}{1+\alpha}\theta + \frac{\alpha}{1+\alpha}\bar{\theta}'.$$

In the text, I have substituted $q = \frac{\alpha}{1+\alpha}$.

is complete. Use $h(.)$ to substitute for q_t, obtaining $\theta' = h(\Omega_t)\bar{\theta} + [1 - h(\Omega_t)]\,\theta$. It is straightforward to show that $\theta = \frac{\theta' - h(\Omega_t)\bar{\theta}}{1 - h(\Omega_t)}$. This transformation means that expected utility for an agent in the second-period of life can be equivalently characterized as either

$$EV(.) = \int_0^\infty V\left[r\left(\theta\right)s + a\left(\theta\right) - \tau\right] g\left(\theta|\Omega\right)d\theta$$

or, more generally

$$EV(.) = \int_{h(\Omega_t)\bar{\theta}}^\infty V\left[r\left(\theta\right)s + a\left(\theta\right) - \tau\right] g\left(\frac{\theta' - h(\Omega_t)\bar{\theta}}{1 - h(\Omega_t)}\right)d\theta'$$

So, the change in expected second-period utility is

$$-V\left\{r\left[h\left(\Omega\right)\bar{\theta}\right]s + a\left[h\left(\Omega\right)\bar{\theta}\right] - \tau\right\}h'\left(.\right)\bar{\theta} + \int_{h(\Omega_t)\bar{\theta}}^\infty V(.)g'\left(.\right)\left\{\frac{h'\left(.\right)\left(\theta' - \bar{\theta}\right)}{\left[1 - h\left(.\right)\right]^2}\right\}d\theta' \tag{8}$$

By, construction, equation (8) is positive. The concrete example adds some additional structure to the general form above. In particular, there is a particular description about how fed watching transforms the random variable. This feature is subsumed in the modified density function embodied in $g'\left(\theta|\Omega\right)$ in equation (6). The example depicts the role played by stochastic dominance, but also adds a role for learning. As equation (8) shows, the density function is transformed by a small increase in fed watching. In addition, changes in q captures the change in the probability weight given to each possible money growth rate. As such, it seems natural to refer to the rate of change in the weighting scheme, $h'(.)$, as learning. Both learning and stochastic dominance are then incorporated into the calculation of second-period utility to the agent's preferences for second-period consumption.

For this particular case, there is still the question about whether $\Omega > 0$ in equilibrium. The first-order condition is

$$\rho U'\left(y - s - \rho\Omega\right) = \mathsf{z}_1 + \mathsf{z}_2 \tag{9}$$

where

$$\mathsf{z}_1 \equiv -V\left\{r\left[h\left(\Omega\right)\bar{\theta}\right]s + a\left[h\left(\Omega\right)\bar{\theta}\right] - \tau\right\}h'\left(.\right)\bar{\theta}$$

and

$$\mathsf{z}_2 \equiv \int_{h(\Omega_t)\bar{\theta}}^{\infty} V\left\{r\left[h\left(\Omega\right)\bar{\theta}\right]s + a\left[h\left(\Omega\right)\bar{\theta}\right] - \tau\right\}g'\left(\theta'\right)\left\{\frac{h'\left(\Omega\right)\left(\theta' - \bar{\theta}\right)}{\left[1 - h\left(\Omega\right)\right]^2}\right\}d\theta'$$

The "shut-down" condition–the condition in which agents would not acquire any costly information about the fed–requires that the marginal utility of first-period consumption is greater than the marginal increase in expected utility evaluated at $\Omega = 0$. Thus, for agent to do some fed watching, the following fed-watching condition must hold:

$$U'\left(y - s\right) < -V\left[r\left(0\right)s + a\left(0\right)\right] - \tau + \int_0^{\infty} V\left[r\left(0\right) + a\left(0\right) - \tau\right]g\left(\theta|0\right)h'\left(0\right)\left(\theta' - \bar{\theta}\right)d\theta' \tag{10}$$

Thus, equation (10) states what condition must be satisfied for an interior solution for fed watching. We will also be interested in the other corner solution; that is, the one in which all messages are acquired.

4 Secrecy, welfare and economic activity

In this section, I consider the effects that changes in the processing fee, ρ, have on the agent's welfare and on the level of saving. Because the agent takes the processing fee as given, these results carry over to a more general setting in which the central bank sets the value of the processing fee. I begin by focusing on the intensity of fed watching.

The first finding examines the impact that a positive processing fee has on the agent's welfare. The following proposition characterizes the welfare consequences.

Proposition 1 An increase in the processing fee of government messages, ρ, reduces lifetime expected utility of all generations born at date t > 1.

Proof: For the case in which the agent's acquire some positive quantity of central bank messages, the effect on lifetime utility is

$$-\omega U'(.)$$

The expression is clearly negative. Thus, agent's are worse off when there is an increase in the processing fee.¥

The intuition for Proposition 1 is straightforward. An increase in the processing fee, for instance, means that the agent must forego a larger quantity of first-period consumption to acquire the same number of messages. From equation 6, the product of the processing fee and the marginal utility of consumption when young increases when ρ increases. With $U(.)$ concave, the product is reduced by consuming more when young, crowding out saving and reducing the amount of fed watching. At a very basic level, Proposition 1 distinguishes between an agent's welfare in a perfect foresight economy and the agent's welfare in an uncertain environment. With concave utility functions, the agent is better off when there is no uncertainty about future money growth. This holds when the price of messages is zero.

Remark 1 Proposition 1 is not terribly surprising. Indeed, the upshot is that young agent's would prefer less costly information than more costly. In the limit, as $\rho \to 0$, the agent's consumption of messages would approach full information, and the conditional distribution would degenerate. Hence, as the processing fee approaches zero, the outcome looks exactly like it would in a perfect information setting. Because, I assume that nature chooses the processing fee, the issue of what a benevolent policymaker woiuld choose is moot. It is obvious from Propositon 1 that a benevolent policymaker has nothing to gain from keeping anything from the agent.

Another question is, What effect does a change in the processing fee have on the equilibrium capital stock? Together, the first-order conditions can be used to derive functions for savings and fed watching as functions of the processing fee; that is, $s(\rho)$ and $\omega(\rho)$.

Two additional assumptions are required regarding the agent's preferences.

Assumption 1: Agent's preferences exhibit decreasing absolute risk aversion.

Assumption 2: Total spending on fed watching is a decreasing function of the price of messages.

Proposition 2 An increase in the processing fee for messages results in more saving, and thus, a larger capital stock.

Proof: Substitute the functions–$s(\rho)$ and $\omega(\rho)$–into the first-order conditions (equations (5) and (6)). Differentiate with respect to ρ. Note that the resulting expression from the Euler equation is

$$U''(.)\,s'(.) + U''(.)\left[\omega(.) + \rho\omega'(.)\right] + EV''(.)\left[r(.)\right]^2 s'(.) + dEV'(.)\,r(.) = 0$$

With decreasing absolute risk aversion, the last term on the left-hand side is positive. Assumption 2 implies that the second term is positive.[16] Thus, the first and third term must be negative. Because U'' and V'' are both negative, $s'(.) > 0$ must hold. Because the capital stock is a linear function of the quantity of saving, it follows that a larger capital stock accompanies an increase in the processing fee of the central bank's messages¥

What proposition 2 highlights is the role of uncertainty on the agent's saving. Indeed, the effect on saving owes directly to the agent's preferences regarding risks to second-period consumption combined with the assumption that a higher processing fee reduces the amount of fed watching. In this model economy, therefore, when

[16] An elastic demand for messages is a stronger assumption than one needs. Elastic demand guarentees that the agent's goods available for first-period consumption and saving increase in the face of rising message prices. Moreover, DARA then dictates the breakdown between consumption and saving the face of greater uncertainty.

the processing fee increases, for instance, the agent's equilibrium decision rule is to increase the quantity of capital.

Remark 2 Because only second-period consumption is at risk, the agent responds to greater risk–processes fewer messages regarding next period's money growth rate–by saving more. In the case of a higher processing fee, the outcome is qualitatively the same as that resulting an unexpected, positive money supply shock in the sense that output increases in both cases. According to the theory underlying the Lucas-supply function, however, the mechanism requires the agents are fooled into producing more output. In this setup, an increase in the processing fee means that agents face a riskier distribution. To insure against these risks to second-period consumption, the agent saves more when young, so that more capital is accumulated, and output correspondingly rises when the same agaents reach old age.

5 Secrecy: An equilibrium with imperfect information

In this section, I consider an economy in which the central bank chooses the processing fee. Because the central bank knows its money growth rate, the outcome with a positive processing fee can be interpreted as secrecy. In other words, as long as the agent does not fed watch enough to acquire all the messages, the central bank will know its future plans while agents will have a distribution characterizing future outcomes. Indeed, the positive processing fee goes toward ensuring that the central bank knows future money growth while the private agent faces a distribution of possible future money growth rates. Here, secrecy is present whenever the central bank's distribution of future money growth rates is different than that faced by private agents when making consumption allocations. Hence, secrecy is endogenized.

Proposition 1 says that if the central bank seeks to maximize the agent's welfare, the processing fee would be set equal to zero. In this section, I derive conditions in which the central bank would choose a positive value for the processing fee. In this model economy, the positive processing fee is the outcome of noncooperative behavior.

I begin with a case in which the central bank does not have the same objective function as the private agent. In this model economy, central bank combines it knowledge of date-$t+1$ money growth and setting the processing fee to satisfy its objective. In short, the central bank is active in deciding what combination ρ and θ_{t+1} will satisfy its goals. The presence of this asymmetric information means that purchasing information is part of a game between the central bank and the agent. As such, the equilibrium concept will be modified.

The government's social objective function consists of two parts: (i) seigniorage target and a (ii) capital stock target for the central bank.[17] The seigniorage target and the capital target are assumed to be consistent with the government's social objective function.

Note that if the central bank receives only one target, the agent could infer the future money growth rate from the value of the processing fee. So, the private information game is structured as a sequential game; more specifically, events occur in the following sequence. At the beginning of date t, agent's receive their endowment. Simultaneously, date-t money growth is realized. Next, the central bank is informed about its target seigniorage level, denoted a^* and its target capital stock, denoted k^*.[18] The monetary authority chooses a combination of the processing fee and the date $t+1$ money growth rate that satisfy its objective function. Both the target level of seigniorage and the target capital stock are private information. Lastly, young

[17]The capital stock target can be thought of as socially desirable stock of capital. Given that a reserve requirement is present, Helpman and Sadka (1979) derive conditions in which a government would want to raise revenue from the inflation tax. The seigniorage target is consistent with the Helpman-Sadka analysis.

[18]I assume that nature draws a^* and k^* such that future money growth is consistent with the conditional distribution function.

agents make their allocations, given the value of the processing fee of messages.

For the central bank, note that seigniorage is simply $v_t(m_t - m_{t-1})$. The central bank knows the agent's saving function, $s(\rho)$, taking it as given Next, substitute the money market clearing condition into the expression for seigniorage, writing the result as

$$\lambda s(\rho_t)\left(1 - \frac{1}{\theta_{t+1}}\right) \tag{11}$$

In equation (11), the central bank has two instruments, the processing fee and the money growth rate. It is obvious from equation (11) that for a given processing fee, there is a money growth rate that yields the target seigniorage level. If the central bank only cared about meeting its seigniorage goal, there are many combinations of ρ_t and θ_{t+1} that would satisfy the seigniorage target. Alternatively, with only a seigniorage target, once the processing fee is announced, the agent could infer what next period's money growth rate would be.

To resolve the indeterminacy, let the central bank's objective function be common knowledge, consisting of both deviations from the target level of the capital stock, denoted $k^*$and the costs of inflation. As with the target level of seigniorage, the target level of the capital stock is private information. Since the capital stock is a linear function of the level of the agent's saving, it is possible to relate the processing fee to the capital stock. Thus, let the central bank's objective function be

$$\min(k_t - k^*) + (\theta_{t+1})^2 \tag{12}$$

Equation (12) is a slightly modified version of the objective function used in the policy game literature developed by Kydland and Prescott (1977) and Barro and Gordon (1983a,b). Here k is taking the place of output as the measure of economic activity. The central bank's objective is to minimize costs, which are comprised of two parts: the first is deviations from the target level of the capital stock and the other is the inflation rate. I assume that k^* is drawn such that $s(\rho^*)$ holds for $\rho \geq 0$.

After substituting $s(\rho)$ for the capital stock and using equation (11) for the future money growth rate the central bank's objective function can be rewritten as

$$\min_{\rho_t}\left\{(1-\lambda-\delta)\left(s\left(\rho_t\right)-s\left(\rho^*\right)\right)+\left[1-\frac{a^*}{\lambda s\left(\rho_t\right)}\right]^{-2}\right\} \tag{13}$$

As such, the central bank's problem yields a solution for the processing fee of messages while the agent (subsequently) determines the utility maximizing allocation set, taking the processing fee as given. Here, the equilibrium concept is subgame perfect. The strategy combination, denoted σ^*, is made of the central bank's decision, $\left\{\bar{\rho}_t, \bar{\theta}_{t+1}\right\}$, and the agent's allocation, $\{\bar{c}_{1t}, \bar{s}_t\}$, where the agent's allocation maximizes lifetime utility. Note that strategy combination is subgame perfect if the use of σ^* results in equilibrium play by each participant. In this simple sequential game, $\sigma^*=\left\{\bar{\rho}_t, \bar{\theta}_{t+1}, \bar{c}_{1t}, \bar{s}_t\right\}$ is a subgame perfect equilibrium.

Consider a stationary version of this game. (For this stationary setting, I drop the time subscripts.) A necessary and sufficient condition for the solution to the central bank's minimization program is

$$\frac{(1-\lambda-\delta)}{2}s'(.)-\frac{a^*\lambda^2 s(.)\,s'(.)}{\left[\lambda s(.)-a^*\right]^3}=0 \tag{14}$$

Thus, $\bar{\rho}$ that solves the central bank's problem will be the processing fee such that $\frac{(1-\lambda-\delta)}{2}=\frac{a^*\lambda^2 s(.)}{[\lambda s(.)-a^*]^3}$. With the solution for the processing fee, the central bank chooses the money growth rate that satisfies the seigniorage target. Because of the government's budget constraint, as long as transfers are greater than zero, the money stock will grow. In short, $\theta>1$ will hold for $a^*>0$. Wallace (1981), and others, have shown that $\theta=1$ is the welfare maximizing rate of money growth for the perfect-foresight versions of this economy. As long as a^* is consistent with $\int \theta_{t+1}g(\theta_{t+1}|\Omega_t)d\theta=1$, there is no inherent inflation bias, even in this game in which secrecy is present.

This is a model of central-bank secrecy. The central bank knows what future money growth will and agent's do not. Indeed, here secrecy is active in the sense that the central bank takes actions-sets the processing fee–so that agents will not consume all the messages. The agent must choose how intensely to fed watch, thus translating messages into particular distribution of future money growth rates. As such, it seems natural to interpret the processing fee as an indicator the quality of the central bank's messages. In other words, the more obtuse the central bank is in its communications with agents, the higher the processing fee; that is, the more goods the agent must expend to convert a given message into a transformation of the distribution function.

From this setup, one can derive the following proposition.

Proposition 3 The central bank chooses a level of secrecy, $\rho \geq 0$. Note that the level of secrecy is positively related to the size of the seigniorage target and inversely related to the bond-saving ratio.

Proof: Equation (14) indicates the impact that changes in the seigniorage target and the bond-money ratio have on the central bank's choice of secrecy. The central bank's choice of ρ will satisfy the condition

$$\frac{(1-\lambda-\delta)}{2} = \frac{a^{*}\lambda^{2}s\,(.)}{\left[\lambda s\,(.) - a^{*}\right]^{3}} \tag{15}$$

Differentiate with respect to the bond-deposit ratio (δ) of the seigniorage target (a^{*}), and after some algebra, will permit one to verify the qualitative statements made in Proposition 3.¥

I consider the effects that changes in the parameters would have on central-bank secrecy. For instance, suppose there is an increase in the target level of seigniorage. Differentiate the right-hand side of equation (15) with respect a^{*}. It is straightforward to show that the right-hand-side of equation (15) is positively related to changes in a^{*}. Thus, the central bank will choose to be more secretive-charge a higher price for messages–when the seigniorage target increases. The central bank faces a tradeoff. With a higher seigniorage target, it can raise more seigniorage by inducing more saving. Hence, the incentive to raise the price of messages. However, the potential cost is that with greater saving, the deviation from the target capital stock increases if the level of saving is already above the target level. Because the central bank's problem is convex in the money growth rate and linear in the deviation from the target growth rate, we see that the central bank chooses a higher price of messages when the seigniorage target increases.

Consider an increase in, δ, the bond-deposit ratio. This would be similar to a permanent open-market sale of government bonds. For this case, the central bank raises the price of messages. Here, the intuition is that the increase in the bond-deposit ratio crowds some capital. To come closer to its target capital stock, the central bank wishes to induce more saving. A by-product is that the seigniorage tax base rises, lowering the money growth rate necessary to hits its seigniorage target. Thus, the central bank chooses to be more secretive when there a permanent open market sale.

Suppose agents were to intensify their fed watching. What affect would this have on the central bank's choice of secrecy; that is, the price of messages? Consider a preference shock such that agent chooses more messages for a given price of messages. Further, suppose that increased fed watching crowds out saving. Based on equation (13), a decrease in $s(\rho)$ reduces the central bank's level of utility. From the central bank's perspective, a decline in agent's saving has two effects. First, it means that it is more difficult to hit the central bank's capital stock target. Second, a reduction in saving reduces the seigniorage tax base. The implication is that the central bank will have to increase the money growth rate in order to hit its seigniorage target. Because faster money is costly to the central bank, the central bank is worse off when agent's increase their level of fed watching. This exercise holds the level of secrecy–the price of messages–constant.

Next, consider the effect increased fed watching would have on the central bank's pricing decision. From equation (14), a decrease in saving induces the central bank to raise the price of message. In short, more intense fed watching, for instance, is associated with a more secretive central bank. The intuition is straightforward. The central bank needs to raise the price of messages, inducing agents to save more. With more saving, the central bank can hit its target capital stock and the amount of inflation necessary to hit its seigniorage target declines with the higher message price. Thus, the central bank responds to more intense fed watching by being more secretive. Alternatively, the central bank is more open (less secretive) when an agent chooses a smaller quantity of fed watching.

6 A benevolent government

In this section, I introduce another source of uncertainty. The question is, Would a benevolent government–one that seeks to maximize the welfare of its citizens–prefer a positive processing fee to the outcome in which there is perfect foresight. In contrast to the previous setup, a positive processing fee is not the outcome of some noncooperative play between the government and agents. If the answer to the section's key question is yes, the benevolent government's policy is observationally equivalent to secrecy. However, the motive is to maximize the agent's welfare not part of some noncooperative play.

In this model economy, I make two simplifying assumptions and add one stochastic feature. First, I assume that the return to capital is independent of the quantity of the capital stock. Second, I eliminate government bonds. Hence, the government faces one budget constraint, depicted as follows

$$a_t = v_t \left(m_t - m_{t-1}\right) \tag{16}$$

Equation (16) indicates that the government introduces new money via a lump-sum transfer to old agents. In addition, I include another layer of uncertainty; specifically, the real return to capital can take on either of two values. Formally, let $x \in \left\{x^h, x^l\right\}$, where $\Pr ob\left(x = x^h\right) = \alpha$ and $\Pr ob\left(x = x^l\right) = 1 - \alpha$. Realizations of the return to capital are identically and independently distributed across time. The real return to capital accumulated at date $t-1$ is learned at the start of date t. Thus, neither the central bank nor agents, know the random return at the time each has to makes its decision. Following the realization of the random return to capital, the central bank announces the date-t money growth rate as drawn from the date $t-1$ equilibrium probability distribution function.[19] Following the central bank's money growth announcement, it chooses the processing fee for date-t messages, old agents receive the product of rs, and young agents make their consumption, saving, and fed-watching decision.

By adding uncertain returns to capital, the government might conduct monetary policy to efficiently pool the agent's risk. To focus on the government's problem, I limit attention to alternative decisions. In one decision, the central bank sets the processing fee equal to zero. Obviously, the agent will consume all the messages and the distribution of future money growth degenerates into the case in which future money growth rates are known with certainty. In the second decision, the central bank sets a positive processing fee in order to give it the flexibility to pool return risks.

Consider both cases in a stationary setting. Note that $a = \lambda s \left(1 - \frac{1}{\theta}\right)$. Let s^m denote the level of savings that a representative young person would choose when the money growth rate is known; that is, the processing fee is zero. Thus, the government seeks to maximize the (trivially expected) lifetime utility of the representative young person. I substitute for a using the government budget constraint,. After collecting terms and reducing the expression for second-period consumption, the agent's lifetime utility level is

$$U\left(y - s^m\right) + \alpha V\left\{\left[\left(1-\lambda\right)x^h + \lambda\right] s^m\right\} + \left(1-\alpha\right) V\left\{\left[\left(1-\lambda\right)x^l + \lambda\right] s^m\right\} \tag{17}$$

[19] More precisely, let Ω^* denote the equilibrium quantity of messages acquired by young agents at date $t-1$. In equilibrium, the date $t-1$ conditional probability density function is $g\left(\theta_t|\Omega^*\right)$.

Note that future money growth is absent from the expression for expected second-period utility. Equation (17) indicates only one source of uncertainty, the real return to capital. After the lump-sum transfer is taken into account, the inflation tax and the lump-sum transfer cancel each other out. Hence, the return to savings is independent of the rate of money growth. What is left is the wedge between the return to capital and the return to money, which appears as the coefficient on savings in equation (17).

Alternatively, consider a case in which the government pools interest rate risk. In effect, the policy is equivalent to targeting the interest rate on savings. In practice, this means that whenever the "high" real return to capital was realized, the central bank would select faster money growth. Conversely, when the "low" return was realized, the money growth rate was lower. Overall, the return to savings is constant across the two realizations; that is, $(1-\lambda)\, x^h + \frac{\lambda}{\theta^{\mathrm{h}}} = (1-\lambda)\, x^l + \frac{\lambda}{\theta^{\mathrm{l}}}$, where θ^i for $i = h, l$ denotes the money growth rates for the "high" and "low" states, respectively.

The question is, Would interest-rate targeting result in higher utility than a constant money supply growth rule. Interest-rate targeting means that future money growth is not a degenerate distribution. In other words, $\alpha\%$ of the time $\theta = \theta^h$ while $\theta = \theta^l$ during the remaining $1 - \alpha\%$ of the time. As the reader will see shortly, pinning down the gross real return to savings does not imply that uncertainty is absent from the agent's second-period budget constraint.

In the interest-rate targeting case, the process fee must be greater than zero. The argument is a proof by contradiction. Suppose that the processing fee were equal to zero. The agent would process all the messages and the characterization of the future money growth rate is a degenerate distribution function. Yet, in the interest-rate targeting case, future money growth rate is not characterized by a degenerate distribution. Rather, future money growth is characterized by a discrete, nondegenerate distribution function. Thus, with the processing fee set equal to zero, there is no rational-expectations equilibrium; the objective distribution function characterizing the money growth rate is not identical to the conditional, degenerate distribution function used by the agent. It follows that the processing fee must be greater than zero in the interest-rate targeting case.

$$G(\theta_{t+1}) = \begin{cases} \theta^h, \ if\ x = x^h \\ \theta^l, \ if\ x = x^l \end{cases} \tag{18}$$

I fix the gross real return to saving. Let $\bar{r} = (1-\alpha)\, x^h + \frac{\alpha}{\theta^h} = (1-\alpha)\, x^l + \frac{\alpha}{\theta^l}$, where $\theta^h > \theta^l$. In words, the central bank chooses a faster money growth rate–$\theta_{t+1} = \theta^h$–when the gross return to capital is in the "high" state and slower money growth–$\theta_{t+1} = \theta^l$– when the gross return to capital is in the "low" state. Of course, the government's seigniorage, and old-age transfers, will depend on the realization of the gross return to capital. In the high real return state, $a^h = \lambda s(\rho)\left(1 - \frac{1}{\theta^h}\right)$ whereas in the low real return state, $a^l = \lambda s(\rho)\left(1 - \frac{1}{\theta^l}\right)$. Taking the agent's savings as given, $\theta^h > \theta^l$ implies that $a^h > a^l$.

For young agents, the future money growth rate is stochastic. Let there exist a $\rho^i > 0$ such that $G(\theta_{t+1}|\Omega(\rho^i)) = G(\theta_{t+1})$. Taking the processing fee as given, the conditional distribution of money growth rate is identical to the unconditional objective distribution of future money growth. Thus, the rational expectations condition is taken into account by the benevolent government.[20]

Now, it is possible to characterize lifetime welfare for the agent in the interest-rate smoothing case. Let s^i denote the level of saving in the interest-rate smoothing case. In short, $s^i = s(\rho^i)$.

$$\begin{aligned} & U\left(y - s\left(\rho^i\right) - \rho^i \Omega\left(\rho^i\right)\right) \\ & + \alpha V\left\{\left[(1-\lambda)\, x^h + \lambda\right] s^i\left(\rho^i\right)\right\} + (1-\alpha)\, V\left\{\left[(1-\lambda)\, x^l + \lambda\right] s^i\left(\rho^i\right)\right\} \end{aligned} \tag{19}$$

[20]What if there could be multiple values of ρ that satisfy this rational expectations condition? I assume that the central bank, interested in the agent's welfare, chooses the smallest value.

A comparison of equations (17) and (19) indicates that for any $\rho > 0$ expected lifetime utility is higher in the constant money growth setting than in the interest-rate smoothing setting. Note that money growth does not enter into the expression for expected lifetime utility. Whatever gains are garnered by interest-rate targeting are cancelled by a lump-sum transfer, leaving a stochastic return to capital. In this setup, old-age transfers are also state-contingent, exactly offsetting the revenues from the inflation tax so that money growth does not effectively smooth interest-rate fluctuations.

Another way to see is to compare equations (17) and (19). Note that these two expressions are identical if $\rho = 0$. With $\rho > 0$, fed watching amounts to throwing away goods that could be consumed without benefitting from the reduced uncertainty.

6.1 Government purchases

The inflation tax-transfer scheme plays an important role in the comparison between the money-growth and interest-rate targeting cases. It seems natural to ask, How do things change, if at all, if seigniorage is used to finance government spending rather than old-age transfer payments? More specifically, what if the inflation tax revenues are kept by the government rather than rebated back to agents as a lump-sum payment?

In this model economy, let the government budget constraint be represented by $g = \lambda s(\rho)\left(1 - \frac{1}{\theta}\right)$. Here, the central bank uses newly printed money to acquire goods from old agents, and throws the goods into the ocean. Hence, the government purchases do not provide any direct utility to agents. This setup is equivalent to a setup in which the government must buy goods that are imperfect substitutes for private consumption. As such, I continue to refer to the government here as benevolent, despite the fact that there is a welfare is reduced because of the some goods are not consumed privately. The resulting second-period budget constraint is characterized by the expression $c_2 = rs(\rho) - g$.[21]

I consider the constant-money growth and interest-rate targeting experiments with positive levels of government purchases. In the constant money growth case, seigniorage is known and fixed–equal to $\lambda s\left(1-\frac{1}{\theta}\right)$. There only uncertainty, therefore, comes from the uncertain real return to capital. Thus, lifetime expected utility is

$$U(y-s) + \alpha V\left[(1-\lambda)x^h s + \frac{\lambda}{\overline{\theta}}s - g\right] + (1-\alpha)V\left[(1-\lambda)x^l s + \frac{\lambda}{\overline{\theta}}s - g\right] \tag{20}$$

Alternatively, in the interest-rate targeting case, government purchases are state contingent because seigniorage depends on the realized value of money growth. Expected lifetime utility is represented as

$$U(y - s(\rho) - \rho\Omega(\rho)) + \alpha V\left[\bar{r}s - g^h\right] + (1-\alpha)V\left[\bar{r}s - g^l\right] \tag{21}$$

Use the government budget constraint to substitute for g in equation (20) and for g^h and g^l in equation (21). We can write expected lifetime utility in the constant money growth case as

$$U(y-s) + \alpha V\left\{\left[(1-\lambda)x^h + \frac{2\lambda}{\overline{\theta}} - \lambda\right]s\right\} + (1-\alpha)V\left\{\left[(1-\lambda)x^l + \frac{2\lambda}{\overline{\theta}} - \lambda\right]s\right\}$$

and for the interest-rate targeting case as

$$\begin{aligned}&U(y - s(\rho) - \rho\Omega(\rho)) + \\ &\alpha V\left\{\left[(1-\lambda)x^h + \frac{2\lambda}{\theta^h} - \lambda\right]s(\rho)\right\} + (1-\alpha)V\left\{\left[(1-\lambda)x^l + \frac{2\lambda}{\theta^l} - \lambda\right]s(\rho)\right\}\end{aligned}$$

The next step is to ask, What are the conditions, if any, in which expected lifetime is greater in the interest-rate targeting case than in the constant money growth rate cases?

Assumption (A3): I assume that there exists ρ such that $U(y-s^m) - U\left(y - s^i(\rho) - \rho\Omega(\rho)\right) < \varepsilon$, where $\varepsilon > 0$ is an arbitrarily close to zero.

[21] I adopt this specification to maintain the isolation between the first- and second-period budget constraints. More specifically, the agent only faces uncertainty in the second-period of life.

Here, Assumption A3 permits me to focus on the second-period utility under the constant-money growth and interest-rate targeting cases. As long as the ρ in Assumption A3 is consistent with a rational expectations equilibrium, and long as expected utility is greater in the interest-rate targeting regime, then there is a positive processing fee that the agent is willing to pay to get interest-rate targeting. I proceed with a comparison of expected second-period utility. Formally,

$$\alpha V\left(r_1 s\left(\rho\right)\right)+\left(1-\alpha\right)V\left(r_2 s\left(\rho\right)\right)>\alpha V\left(r_3 s\right)+\left(1-\alpha\right)V\left(r_4 s\right) \tag{22}$$

where

$$\begin{aligned}
r_1 &\equiv \left(1-\lambda\right)x^h+\frac{2\lambda}{\theta^h}-\lambda \\
r_2 &\equiv \left(1-\lambda\right)x^l+\frac{2\lambda}{\theta^l}-\lambda \\
r_3 &\equiv \left(1-\lambda\right)x^h+\frac{2\lambda}{\bar{\theta}}-\lambda \\
r_4 &\equiv \left(1-\lambda\right)x^l+\frac{2\lambda}{\bar{\theta}}-\lambda
\end{aligned}$$

Suppose $\theta^h>\bar{\theta}>\theta^l$. It follows that $r_1<r_3$ and $r_4<r_2$. From this characterization, we obtain the following proposition.

Proposition 4 Suppose $g,\ g^h,\ g^l>0$. With Assumption (A3) and a given positive processing fee, future generations' expected lifetime welfare is higher under the interest-rate targeting regime than under the constant money growth regime if the expected real return to fiat money in the interest-rate targeting case is less than the real return to money in constant money growth case.

Proof. To compare expected utility, we apply stochastic dominance results. Condition (22) holds if the distribution of returns in the interest rate targeting case second-order stochastic dominates the distribution of returns for the constant-money growth case. Formally, $\alpha r_1+\left(1-\alpha\right)r_2<\alpha r_3+\left(1-\alpha\right)r_4$. Expand this expression, using the definitions of r_i for $i=1,2,3,4$. The resulting expression reduces to

$$\left(1-\alpha\right)\left(\frac{1}{\theta^l}-\frac{1}{\bar{\theta}}\right)<\alpha\left(\frac{1}{\bar{\theta}}-\frac{1}{\theta^h}\right)$$

After rearranging, one gets

$$(1-\alpha)\frac{1}{\theta^l}+\alpha\frac{1}{\theta^h}<\frac{1}{\bar{\theta}}$$

where the terms on the left-hand side of the inequality is the expected real return to money in the interest-rate smoothing case and the term on the right-hand side is the real return to money when the money growth rate is constant. ■

Proposition 4 says that a benevolent government would choose a positive processing fee over committing to a constant money growth rate provided the expected real return to saving. In other words, agents would prefer a lower return with certainty combined with smaller expected g, to a case in which expected real returns are higher and government purchases are known.

The intuition behind Proposition 4 is straightforward. With interest-rate targeting, the central bank permits the real return to money to vary depending on the realized state of returns to capital, targeting the real return to saving. If the expected real return to fiat money is less than the real return to fiat money in the constant-money growth setting, the distribution of total resources stochastically dominates the distribution associated with the constant-money growth case. Thus, provided the loss of first-period utility to buying the central bank's messages is small enough, expected lifetime utility is greater under the distribution that stochastically dominates. A benevolent government would prefer to be obtuse–a positive processing fee–than to let $\rho = 0$.

The interest-rate targeting regime is a state-contingent rule. Proposition 4 identifies the conditions in which a state-contingent rule is can be preferred to a noncontingent rule. Indeed, Proposition 4 says that under these conditions, the agent is willing to pay some price to follow the state-contingent rule. In this interpretation, with lump-sum transfer payments, the agent is no worse off in the state-contingent setting if $\rho = 0$. Agents are simply not willing to pay a positive processing fee to get the state-contingent rule when government purchases are in the form of lump-sum transfer payments.

There is some positive value of the processing fee that an agent is willing to pay in order to target the return to saving. Note, however, that the interest-rate targeting does not mean that the second-period income is certain. The level of government purchases is state contingent. With $\rho = 0$, the central bank commits to particular money growth setting, abandoning its ability to apply a rule that state-contingent with respect to the real return to savings. When the returns to capital are uncertain, the conditions in Proposition 4 indicate when the agent would be willing to pay a positive price to target interest rates, at the risk of uncertain government purchases. In effect, Proposition 4 characterizes those conditions in which too much central-bank transparency is harmful. Or, alternatively, opaqueness can lead to expected welfare improvements.

The value of central-bank opaqueness comes from its ability to observe the marginal product of capital before setting the money growth rate. In other words, the central bank can efficiently pool risk and guarantee a fixed return to savings by waiting.[22] Even though government expenditures are uncertain in the interest-rate targeting case, as long as the expected level of government purchases are smaller than they would be in the constant-money growth setting, the agent could be better off in terms of expected lifetime utility. Here, opaqueness is not necessarily a signal of the central bank's malicious intention, or reflective of an adversarial position. Indeed, the results in this last section are derived in the context of a benevolent central bank. Both central bank and the agent face an uncertainty. By targeting interest rates, the central bank is flexible to act when it realizes the random state variable. The alternative is to precommit to particular money growth rule, foregoing the state-contingent rule.

In this model economy, the central bank observes the return to capital before it sets the money growth rate. This assumption greatly simplifies the identification problem

[22] After taking government purchases into account, the coefficient on savings is state contingent. Here interest-rate targeting refers to the rates at which an agent converts first-period consumption good into second-period consumption good, abstracting from the effects of government purchases.

faced by a central bank. Making the central bank's signal-extraction problem more substantial, however, does not necessarily overturn the results. For instance, suppose that at date $t+1$, the central bank observes a distribution of returns to capital instead of the particular real return to capital. As long as the central bank's distribution yields an improvement, on average, over a fixed-money growth rate strategy, expected welfare will be higher. The value of opaqueness comes from the central bank's information set available at date $t+1$ compared with the information set available at date t; that is, the central bank can wait, rather than precommit. In short, what matters is that the central bank picks the money growth rate that, on average,

It should be clear from the description of the model economy that the absence of central-bank transparency is not equivalent to central-bank secrecy. At the time that messages are acquired by agents, the central bank does not know anything more about the return to capital than agents do. However, with interest-rate targeting, the agent's information set at date t–when the consumption-saving decision is made–is a proper subset of the central bank's information at the time–date $t+1$–that the central bank must choose its money growth rate. As such, Proposition 4 characterizes an opaque central bank, not a secretive one and it identifies the conditions in which such opaqueness is valuable to the agent. I have only looked at a comparison in which the central bank efficiently pools interest-rate risk. In this model economy, only interest-rate risks are present. Other state-contingent rules would apply as the central bank observes other kinds of risk.

Note that interest-rate targeting implies that government purchases are procyclical. When capital's return is high, money growth is faster and government purchases are higher. Compared with the level of government purchases in the constant money growth regime, Proposition 4 implies that government purchases are, on average, lower in the interest-rate targeting regime.

Thus, I have shown that a benevolent government will choose to be opaque. It is interesting that opaqueness is the means to efficiently pooling interest-rate risk in this model economy. More concretely, efficient risk pooling is consistent with interest–rate targeting, smaller government, on average, and procyclical government revenues as distinguishing characteristics compared with the regime in which transparency depicts central bank behavior.

7 Summary and conclusion

In this paper, I use a simple general equilibrium model to examine the role of fed watching in two settings. In this setup, fed watching is the act of processing central bank messages. Though the messages can be acquired for free, the value of the message comes from studying them and drawing inference about the central bank's future actions. I model such private activities as a processing fee that is paid for with units of the consumption good. More specifically, I consider a processing fee as the rate at which goods are expended to transform a message into a change in the distribution of future money growth rates. Messages are standardized so that the processing fee is constant per message. As such, fed watching can be thought of as agent's choice over alternative distribution functions. The first part of the paper is devoted to deriving conditions in which a private agent will pay a positive price to process the central bank's messages.

The second part of the paper seeks to account for why a central bank would be opaque. I begin with a case in which the central bank's objective function differs from the agent's objective function. In equilibrium, the central bank knows what its future money growth rate will be and sets the processing fee to keep agents from consuming all of the messages. Insofar as the agent does not process all of the messages, the central bank is being secretive. I can show an interesting corollary in this setting; that is, the equilibrium level of secrecy is greater when governments rely more heavily on the central bank for seigniorage. There is certainly an impression that central banks in undeveloped countries are more opaque than those in more developed countries. Insofar as undeveloped countries also may rely more heavily on the inflation tax as a revenue source, this corollary could account for less transparency in undeveloped countries.

Suppose that the central bank wishes to maximize the objective function of a private agent. I derive the conditions in which the central bank would set a positive processing fee for its messages in this case. Though the two settings yields qualitatively similar outcomes in terms of a positive processing fee, it is difficult to interpret the government as being secretive. In this setting, there is no private information, the central bank is opaque with respect to its future actions. Here, opaqueness gives the central bank leeway to follow the state-contingent rule that raises the representative agent's welfare. In other words, the central bank offers less-than-clear messages, requiring people to exert effort to interpret their meaning, in order to execute the best wait-and-see policy it can.

Both secrecy and opaqueness share one fundamental attribute. Namely, the agent does not process all the central bank's messages, so that the central bank's future actions are not fully revealed. It is simply too expensive for the agent to expend enough resources to yield a transparent central bank. In the setting with secrecy, the central bank is acting noncooperatively, perhaps maximizing social welfare. In contrast, opaqueness is a welfare-improving outcome–the central bank is opaque in order to apply the efficient state-contingent rule.

Though interest-rate targeting versus money-growth targeting is not the central theme of this paper, the results offer a theoretical explanation for why interest-rate targeting is preferred to a money-growth rule. Poole (1970) demonstrated the conditions in which an interest-rate target would reduce output variability. Both Carlstrom and Fuerst (1995) and Rebelo and Xie (1999) show that interest-rate targeting is efficient. Carlstrom and Fuerst argue that the interest-rate peg reduces distortions in an economy subject to both productivity shocks and government spending shocks. Rebelo and Xie demonstrate that the interest-rate target yields Paretoefficient allocations in a continuous-time monetary growth model. Following both of these papers, I use welfare criterion to assess the desirability of interest-rate targeting versus money-growth targeting. Carlstrom and Fuerst look at an economy in which monetary policy distorts both the consumption-saving decision and the labor-leisure decision. Because the theorem of the second-best applies, they use numerical analyses to compare welfare under the interest-rate peg and the money-growth peg. In this paper, there is not labor-leisure tradeoff. However, the sufficiency conditions derived here apply in the second-best setting. As such, this paper goes part way toward assessing the efficiency issues raised by Carlstrom and Fuerst.

Several extensions come to mind. One is to investigate the transition dynamics. Throughout this paper, I focus on stationary settings. It is natural to wonder what is the appropriate course along the transition path. Along the transition path, it may be possible to talk about reputation-building and credibility. In other words, perhaps there are instances in which the central bank produces "bad" messages. Such concepts do not lend themselves to static exercise such as those developed here. In addition, the representative agent is quite tractable, but fails to consider the role of heterogeneity among agents. With heterogeneous agents, one could investigate the role, if any, coming from agents with different choices of fed watching.

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