On Fed Watching and Central Bank Transparency in an Overlapping Generations Model

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Working Paper 0002

Federal Reserve Bank of Dallas

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July 20, 2001

Abstract

I develop a simple general equilibrium model that integrates fed watching with central bank opaqueness. With the intergenerational conflict, opaqueness can solve a Ramsey problem. With monetary uncertainty as the only source of randomness, transparency is the welfare maximizing policy. With other sources of variation, transparency is costly in the sense that it limits the central bank's response to intrinsic shocks. In short, opaqueness is the veil that permits the central bank freedom to choose money growth in a way to raise welfare.

*I have benefitted from conversations with Joydeep Bhattacharya, Michelle Garfinkel, Gerhard Glomm, Greg Huffman, Pete Klenow, Evan Koenig, Jack Meyer, Rowena Pechenino, Neil Raymon, Chris Waller, Carlos Zarazaga, seminar participants at the Federal Reserve Banks of Dallas and St. Louis, Michigan State University, Notre Dame University, Texas A&M University and, especially, Scott Freeman. None can be held accountable for remaining errors.

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 is an insightful, albeit casual, piece of empiricism, stressing two stylized facts. The first point is that people expend resources to discern what central bankers say; that is, Fed watch. By doing so, uncertainty about future monetary policy actions is lessened. The second point recognizes that central bankers regularly communicate aspects of their future actions. The fact that such communications do not yield precise, or equivalently a degenerate distribution, of these future actions is indicative of central bank opaqueness.

The purpose of this paper is to examine the question, Under what conditions would this institutional arrangement–that is, a world with central bank opaqueness–be an equilibrium outcome? I develop a simple overlapping generations model to analyze this question. Finite life is a simple way to introduce conflict a la' Chari, Kehoe and Prescott (1989). Indeed, the intergenerational conflict inherent in the overlapping generations is the driving mechanism at work in this model.

The central bank is solving a Ramsey problem. Specifically, what level of opaqueness maximizes the lifetime of current and future generations? Here, fed watching is explicitly linked to the notion of central bank opaqueness.[1] Indeed, fed watching is costly if and only if the central bank is opaque. With a transparent central bank, no resources are used to fed watch. In this setup, it possible to obtain the classic result that more information is better.[2] The solution to the Ramsey problem is

[1] See Rudin (1988) and Balke and Haslag (1992) for models in which there is fed watching in a reduced-form model economy.

[2] Hence, this model economy formalizes the arguments made in Goodfriend (1986). See also

for the central bank to be transparent if monetary uncertainty is the only source of randomness that an agent faces. I extend the model to consider additional sources of randomness–that is, intrinsic uncertainty. I derive conditions in which the central bank would choose to be opaque in this more general setting.

The chief difference this paper and the existing literature is that the agent's choice problem is an explicit maximization program. Previous efforts have modified the reduced-form models developed in Kydland and Prescott (1977) and Barro and Gordon (1983a,b). Some appeal to the Theorem of the Second-Best is at the heart of these arguments; deviations from the first-best money growth rate can potentially raise welfare in such a model economy with some distortion or conflict.[3] Notably, Cukierman and Meltzer (1986) and Faust and Svensson (1999) derive conditions in which opaqueness raises welfare compared with transparency. In the Cukierman-Meltzer (reduced-form) framework, opaqueness provides cover for the central bank, permitting a lower inflation bias than if the central bank were transparent. Faust and Svensson sever the link between the incentive to create surprise inflation and the inflation bias. Agent use means other than the inflation bias to punish an opaque central bank. Because of an inherent conflict of interest, the central bank seeks to minimize the equilibrium inflation rate. In these two papers, an opaque central bank may be able to achieve a lower average inflation rate than a transparent one. Because of the intergenerational conflict present, there is a possible role for opaqueness. The young prefer transparency because they avoid using resources for anything other than consumption. The old, however, benefit from the degree of freedom that opaqueness provides. In the presence of intrinsic uncertainty, the central bank can observe the realization and then choose monetary policy actions that results in greater old-age consumption. Over one's lifetime, opaqueness is preferred if the costs of monetary

the redued-form models presented by Grossman and Stiglitz (1980), Dotsey (1987), and Tabellini (1987). Blinder (1998) articulates a political economy argument for transparency.

[3]See Chari, Kehoe and Prescott (1989) show that conflict is essential for time consistency to be a problem.

uncertainty are not too great vis a' vis the costs of fed watching.

In this paper, the central bank's announcements are treated differently than they are in the existing literature. Previously, researchers have adopted the notion of noisy signals to model opaqueness. Transparent announcements are simply ones in which the signal is perfect. Here, I use a variant of the noisy signal approach. I assume that central bankers offer a measure of announcements each period. The announcements can be acquired at zero cost. Moreover, this communication is marginally credible in the sense of Cukierman (1992). In other words, each additional communication results in a stochastically dominant distribution of future money growth rates. To achieve this transformation in the distribution function, the agent must process the announcement to glean its valuable content. Fed watching measures the resources expended to discern the content. Processing the full measure of the announcements is equivalent to knowing precisely what the central bank will do next period. Because of the processing cost, the optimizing agent may not process the full measure. For this analysis, the notion of opaqueness relates to how easy it is for agents to translate these messages into changes in the distribution of future money growth rates. The more obfuscated the messages are, the greater the processing fee, and the more resources an agent must expend to understand a given quantity of central-bank announcements and update their money growth forecasts. Fed watching, therefore, is the quantity of resources expended to transform the distribution function.

There is no asymmetric information in this setup. When date t begins, the central bank chooses the money growth rate that maximizes welfare. Central bankers know the intensity of fed watching and at date $t+1$ choose a money growth rate from that distribution. At date t, the central bank does not know what its money growth rate will be. The link is between date t actions by agents and date $t+1$ money growth is the intensity of fed watching. Because the central bank is not in conflict with the agent, central bankers are assumed to be willing to choose future money growth rates from the equilibrium (predetermined) distribution function. Even in such a setup, there is a possible role for opaqueness to minimize lifetime cost over a finite planning horizon.

One final result pertains to the intensity of fed watching over time. Two conditioning factors form the agent's beliefs: common knowledge and fed watching. Common knowledge can be thought of as all the free information available to agents without fed watching, including the primitives of the model economy. In addition, common knowledge evolves over time with fed watching augmenting common knowledge. A stationary stochastic setting with an ergodic distribution of future money growth rates, I show that the intensity of fed watching diminishes. As agents accumulate sufficient common knowledge, fed watching is no longer worth doing. Because fed watching is decreasing in the processing cost, it follows that common-knowledge accumulation is retarded by higher precessing fees.

Monetary uncertainty may result in higher lifetime welfare. However, these results show that some significant hurdles come into play. There are real costs associated with the communication between the central bank and private agents. As such, the gain from monetary uncertainty today must be more than offset by improvements in realized monetary policy actions. Even so, the benefits to future monetary policy action depend on primitives in the agent's preferences; the saving response to additional monetary uncertainty must be large enough to compensate people for the added cost of fed watching.

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 the demand for saving and fed watching. In Section 5, I examine 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 6.

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 $V(c_{21})$.

In order to smooth consumption over one's lifetime, a young agent exchanges the consumption good for assets. Two assets exist: fiat money and 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 the production process. It takes v_t units of the consumption good for one unit of fiat money at date t. One period later, the agent can purchase v_{t+1} units of the consumption good with each unit of money. Let s denote saving so that the agent's storage is represented as $s_t = k_t + v_t m_t$, where m is the number of dollars per young agent.

In order to ensure that fiat money is valued, I follow Bryant and Wallace (1980), applying a legal restriction. A fraction of saving must be in the form of money; formally, $v_t m_t = \lambda s_t$. Here, $0 \leq \lambda \leq 1$. The restriction is binding for $\frac{v_{t+1}}{v_t} \leq f'(k_t)$. Thus, as long as money does not rate of return dominate capital, the real return to saving is $\lambda \frac{v_{t+1}}{v_t} + (1-\lambda) f'(k_t)$.

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 and fiat money, denoted by m_0; in short, $s_0 = k_0 + v_1 m_0$. The utility of the initial old is strictly increasing in the quantity of the consumption good. The stock of money evolves according to the rule, $m_t = \theta_t m_{t-1}$, where θ is the money growth rate.[4] Money is created and distributed as lump-sum transfer payment to agents when old; that is, $a_t = (\theta_t - 1) v_t m_{t-1}$ goods are transferred to members of the generations born at date $t-1$.

The future money growth rate is a random variable. Second-period incomes are therefore random. Because the return to money is positively related to the money growth rate, the gross real returns to savings is random. In addition, the old-age transfer payment is a random variable. Throughout this analysis, old-age utility is a random variable.

In this paper, the central bank has three distinct functions: creating money, making lump-sum transfer payments, and making announcements. As noted above, money creation finances old-age payments. The novelty in this paper is the notion of announcements. Central bank announcements consist of a continuum of messages with unit measure.[5] The central bank does not sell the measure of announcements.

[4] 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.

[5] See Allen (1989) for description of an economy in which there is costly, differentiated information. In addition, Allen treats information as an ordered sequence, citing a ticker tape as an appropriate

Rather, the full measure is produced at zero cost and released freely to agents. Central bank announcements are costly to process. The agent expends ρ date-t goods to translate the full measure of announcements into a transformation of the distribution function. The processing fee, ρ, represents the ease with which agents can modify the distribution function; that is, learn about future money growth rates. The greater the obfuscation of central bank announcements, the greater is ρ.

From the agent's perspective, fed watching is the act of processing the announcements. In addition, the agent is endowed with free information. This information set, denoted Ω, consists of any common knowledge items, including an entire history of money growth rates. To permit this common knowledge to change over time, I assume that $\Omega_{t+1} = H\left(\Omega_t, \omega_t\right)$ denotes the law of motion describing the evolution of the free information. In short, the measure of processed announcements becomes common knowledge for next period. The agent is endowed with a technology such that processing central bank announcements updates the distribution function. Let $G(\theta_{t+1}|\Omega_t)$ denote the distribution function for the money growth rate conditional on an agent abstaining from fed watching; that is, $\omega_t = 0$. For the sake of interests, I assume that $G(\theta_{t+1}|\Omega_t)$ is a nondegenerate distribution. The distribution function is twice continuously differentiable, with the first derivative yielding a density function, denoted $g(\theta_{t+1}|\Omega_t)$. 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.

Now, consider a case in which $\omega_t > 0$. The appropriate distribution is $G(\theta_{t+1}|\Omega_t, \omega_t)$. The technology results in a transformation of the conditional distribution function. With credible messages, the technology results in $G(\theta_{t+1}|\Omega_t, \omega_t)$ stochastically domi-

analogy. In words, the agent must process the messages moving along the line from zero to one, never skipping messages to get to a point closer to one. One can imagine that messages represent points on a unit circle. The agent, therefore, is limited to one-way travel.

nating $G(\theta_{t+1}|\Omega_t)$. Indeed, the transformation is continuous such that $G(\theta_{t+1}|\Omega_t, \omega_t + \varepsilon)$ stochastically dominates $G(\theta_{t+1}|\Omega_t, \omega_t)$ where $\varepsilon > 0$. With $\omega_t = 1$, I assume that for any Ω_t, the technology yields a degenerate distribution so that $G(\theta_{t+1}|\Omega_t, 1) = \bar{\theta}$, where $\bar{\theta}$ denotes the money growth rate that will be realized at date $t+1$.

Thus, there are two types of learning in this model. One is the accumulation of common knowledge. The learning is captured by the $H(.)$ function. Another type is the knowledge is costly to acquire. Thus, the agent is endowed with a technology that transforms knowledge, both free and costly, into an update distribution of future money growth rates.

I turn my attention to three concepts that have garnered a lot of attention in this literature: transparency, credibility, and reputation. Transparency and opaqueness are linked to the distribution of the future money growth rates. Here, the notion of transparency corresponds naturally to a degenerate distribution function. The processing fee is also linked to the notion of transparency. Note that the processing fee describes the ease with which an agent can agent transform the distribution of future money growth rates. Transparency is present if (i) $\rho_t = 0$; or (ii) there is a corner solution with $\rho_t > 0$ and $\omega_t = 1$. In the first case, the agent can freely acquire all the central bank announcements and know with certainty the future money growth rate. This is the supply side of complete transparency. The corner solution also yields compete transparency because the agent demands the full measure of central bank announcements at the given processing fee. In both instances, $\theta_{t+1} = \bar{\theta}$ with perfect foresight.

The notion of credibility is related to the transformation of the distribution function. Here, I borrow Cukierman's (1992) notion of marginal credibility.[6] More specifically, marginal credibility is defined as "how much a unit change in announced targets changes inflationary expectations" (p.157). As the quote suggests, Cukier-

[6]Note that this notion of credibility is consistent with Blinder (1998)–the central bank's future actions match its words.

man is primarily interested in how announcement affect the expected inflation rate, I will generalize his notion somewhat by letting announcement affect the entire distribution of future money growth rate. I assume that the distribution with a greater measure of processed announcements stochastically dominates a distribution with a smaller measure of processed announcements. Thus, the change in expected utility is positively related to ω. I also assume that an increase in ω results in diminishing gains in expected utility.

The central bank's reputation is a summary of past observable actions. This history is embodied in the common-knowledge information represented by Ω_t. The division between common knowledge and costly fed watching is clear within the context of the model economy. I think of the distinctions as reasonable in the sense that reputations are built on common perceptions of the policymakers history. In contrast, fed watching adds to the reputation by permitting the agent to augment the history with, possibly costly, current insights.

2.2 The agent's program

Thus, the young's budget constraint is represented by

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

and that of the old agents is represented as

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

Here, r is the gross real return to savings and τ is a lump-sum tax paid to the government when old.

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,

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

Because both the gross real return to saving and the old-age transfer payment is a function of the random variable, I can write $r_{t+1} = r\left(\theta_{t+1}\right)$ and $a_{t+1} = a\left(\theta_{t+1}\right)$. Thus, the expected second-period utility is written as

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

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

$$-U'\left(.\right) + \int_0^\infty V'\left[.\right] r\left(.\right) g\left(.\right) d\theta = 0 \tag{3}$$

and

$$-\rho_t U' + \int_0^\infty V\left[.\right] g'\left(\theta_{t+1} | \Omega_t, d\omega\right) d\theta = 0 \tag{4}$$

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. To save on notation, I will use $\Delta EV\left(.\right) \equiv \int_0^\infty V\left[.\right] g'\left(\theta_{t+1} | \Omega_t, d\omega\right) d\theta$.

Equation 3 is a 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 4 is captures the tradeoff associated with fed watching. To increase fed watching, the agent must give up units of the consumption good. The marginal utility loss is $\rho_t U'(.)$. Fed watching yields benefits equal to the marginal increase in expected second-period utility. If announcements were not credible, the marginal gain would be negative and no fed watching would occur. Credibility, however, is not sufficient to guarantee an interior solution. Fed watching has to be valuable enough for an agent to process some positive measure of central bank announcements.[7]

Stochastic dominance is not a sufficient condition for agents to fed watch. To illustrate this point, consider an arbitrarily small measure of processed messages denoted $\hat{\omega} = \epsilon$, where $\epsilon > 0$ is arbitrarily small. Accordingly, the two density functions are $g\left(\theta_{t+1}|\Omega_t, \hat{\omega}\right)$ and $g\left(\theta_{t+1}|\Omega_t\right)$, respectively. Thus, the change in expected utility is

$$\Delta EV\left(.\right) = EV\left[.\right]|_{\hat{\omega}} - EV\left(.\right)$$

Stochastic dominance insures that the expression is positive.[8] There is not guarantee that it exceeds $\rho_t U'\left(.\right)$. An interior solution will be obtained if $\lim_{\omega \to 0}$ $\Delta EV\left(.\right) = \infty$.

The presence of fed watching is implicitly tied to the stock of common knowledge. In this model economy, fed watching adds to the stock of common knowledge. As such, there is a result that eventually fed watching will vanish. I assume that $\Delta^2 EV\left(.\right) < 0$. In words, as common knowledge is accumulated, there is less value added by fed watching. Hence, with a positive processing fee, the intensity of fed watching diminishes as the agents gains common knowledge. To see this, recall the agent's first-order condition: $-\rho_t U' + \int_0^\infty V\left[.\right] g'\left(\theta_{t+1}|\Omega_t, d\omega\right) d\theta = 0$. Remember that $\Omega_{t+t} = H\left(\Omega_t, \omega_t\right)$. With $H_\omega > 0$, the agent is accumulating common knowledge through fed watching. Thus, there exists some value of common knowledge, call it, Ω^*, such that $\omega_t = 0$ for all $\rho_t > 0$ and $\Omega_t \geq \Omega^*$. The shut-down condition for fed watching is met. What is interesting, is that there is a dynamic transition to zero fed watching as common knowledge increases over time.

[7]The second-order conditions for a maximum require that the Hessian matrix is positive definite. These conditions are satisfied with risk averse agents and if the change in expected marginal utility is "small. Formally, $\left[\Delta EV''(.)\left(r_{t+1}\right)^2\right] \times \left[\Delta^2 EV\left(.\right)\right] >$ $\left[\Delta EV'\left(.\right) r_{t+1}\right]^2$.

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

2.3 Equilibrium

For this model economy, a rational expectations competitive equilibrium for this model economy consists of a sequence of functions for agent's allocations–$\{c_{1t}\}, \{c_{2t}\}, \{s_t\}, \{\omega_t\}, \{k_t\}, \{$ prices, $\{v_t\}$ and $\{r_t\}$ and policy settings $\{\theta_t\}, \{\rho_t\}$, and $\{\lambda_t\}$ such that

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

(ii) markets clear and the government budget constraint [equation **??**] is satisfied;

(iii) The objective distribution function characterizing the random variable θ_{t+1} is identical to the agent's subjective distribution function.

Notice the realized gross real return to saving is[9]

$$r_t = (1-\lambda) f' [(1-\lambda) s_{t-1}] + \lambda \frac{v_t}{v_{t-1}} \ \forall t \geq 2 \tag{5}$$

Equation 5 indicates that the gross real return to savings is a weighted sum of capital and fiat money. The weight is the share of the agent's assets shares.

In the next section, I consider a particular member of the class of processing technologies. I focus on a case in which the expected rate of money growth is invariant to the intensity of fed watching. This imposes restrictions on the form of stochastic dominance. Specifically, the distribution $G(\Omega_t, d\omega)$ exhibits second-order stochastic dominance in relation to the distribution $G(\Omega_t)$ and is a general version of the mean-preserving contraction used by Faust and Svensson.

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

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

supports; that is, $0 \leq \theta_* < \theta^*$ The effect of a change in fed watching is captured as 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 $0 < q < 1$.[10] Here, $\bar{\theta}$ denotes the mean, or expected money growth rate for the density function $g(\theta|\Omega_t)$. 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, as q increases, less weight is placed 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 measure of announcements processed. In other words, let $q_t = h(\omega_t)$. The $h(.)$ function has the following properties: $h(0) = 0$, $h[1] = 1$, $h'(.) > 0, h''(.) < 0$. These properties have the following economic interpretation. If the measure of announcements processed equals zero, $q = 0$ and the conditional density function for θ' is the same as the conditional density function for θ. If, however, the agent processes the full measure of messages, 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 processing a larger measure 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 processing messages. Finally, $h''(.) < 0$, asserts that the marginal payoff to message acquisition to the agent is diminishing in ω.

[10] 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 $q = \frac{\alpha}{1+\alpha}$.

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

$$EV(.) = \int_0^{\infty} V\left[r(\theta)\,s + a(\theta)\right] g\left(\theta|\Omega_t, \omega_t\right) d\theta$$

or, more generally

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

So, the change in expected second-period utility is

$$-V\left\{r\left[h(\omega)\,\bar{\theta}\right] s + a\left[h(\omega)\,\bar{\theta}\right]\right\} h'(.)\,\bar{\theta} + \int_{h(\omega_t)\bar{\theta}}^{\infty} V(.) g'(.) \left\{\frac{h'(.)\left(\theta' - \bar{\theta}\right)}{\left[1 - h(.)\right]^2}\right\} d\theta' \quad (6)$$

By, construction, equation (6) 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 $g'\left(\theta|\Omega_t, \omega_t\right)$ in equation (4). The example depicts the role played by stochastic dominance, but also adds a role for learning. As equation (6) 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.

It would be useful to know the "shut-down" conditions for fed watching. In other words, there is still a question about whether $\omega > 0$ in equilibrium. Recall that the first-order condition is $\rho_t U'\left(y - s_t - \rho_t \omega_t\right) = z_1 + z_2$ where

$$z_1 \equiv -V\left\{r\left[h(\omega_t)\bar{\theta}\right]s_t + a\left[h(\omega_t)\bar{\theta}\right]\right\}h'(.)\bar{\theta}$$

and

$$z_2 \equiv \int_{h(\omega_t)\bar{\theta}}^{\infty} V\left\{r\left[h(\omega_t)\bar{\theta}\right]s_t + a\left[h(\omega_t)\bar{\theta}\right]\right\}g'(\theta')\left\{\frac{h'(\omega_t)\left(\theta' - \bar{\theta}\right)}{\left[1 - h(\omega_t)\right]^2}\right\}d\theta' \qquad (7)$$

The "shut-down" condition is a corner solution; that is, the condition in which agents would not acquire any costly information about the fed. In equation (7), the marginal utility of first-period consumption is greater than the marginal increase in expected utility evaluated at $\Omega = \Omega_t$, or equivalently, $\omega_t = 0$. Thus, for fed watching to be positive, following condition must hold:

$$U'(y - s) < -V\left[r(0)s + a(0)\right] - \tau + \int_0^{\infty} V\left[r(0) + a(0) - \tau\right]g\left(\theta|\Omega_t, 0\right)h'(0)\left(\theta' - \bar{\theta}\right)d\theta' \qquad (8)$$

Thus, equation (8) 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 The effects of a change in ρ

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. I am interested in obtaining the solution to the Ramsey problem; that is, what level of the processing fee yields the highest welfare level? I derive the effects that different values of ρ have on saving and 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

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

■

With $\omega_t > 0$, welfare is declining, for instance, for a given increase in the processing fee.

The intuition for Proposition 1 is straightforward. There is no other uncertainty in this model economy. If the future money growth rates is uncertain, risk-averse agents would suffer a welfare loss. It is straightforward for the central bank to raise welfare by making its announcements costless to process. In other words, the central bank becomes transparent so that uncertainty is eliminated.

There are general equilibrium effects that one can examine in this setup. For instance, it is possible to determine the effects that changes in the processing fee have on savings.

Proposition 2 At $\rho_t = 0, s'(\rho_t) < 0$ and $\omega'(\rho_t) < 0$.

Proof: See the appendix.

Proposition 2 highlights is the role of uncertainty on the agent's saving. The experiment asks how a change from a transparent central bank to an opaque one affects the agent's level of saving. The results indicate that a increase in the processing fee, for example, results in agent's saving less when we start with a central bank that is transparent. Both the transfer payment and the return to saving become uncertain as the processing fee increases. The optimizing agent responds by substituting for more consumption in the certain period; that is, when young. By stretching a degenerate distribution, there is only a substitution effect. This finding further implies that capital accumulation is inversely related to the processing fee.

The second result asks the effect of the change in the processing fee on the intensity of fed watching. As the central bank switches from being transparent to being opaque, fed watching becomes more expensive and agents choose to watch less intensely. Consider the impact of a change in the processing on the accumulation of common knowledge. With $H_\omega > 0$ it follows that an increase in the processing fee results in common knowledge being accumulated at a slower rate.

In absence of any uncertainty, a central bank will not introduce uncertainty by being opaque. The welfare maximizing policy is to be transparent.

5 A model with intrinsic uncertainty

In this section, I derive conditions in which benevolent government would choose a positive processing fee. The key feature is that I introduce a source of aggregate uncertainty into the model. The central bank can potentially raise welfare but it must be opaque in order to respond to the intrinsic uncertainty. In addition, I will also address that arises as agents "learn" the policy environment.

Suppose that the marginal product of capital is independent of the quantity of the capital stock. In addition, the marginal product of capital is a random variable. 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 timing in this model economy is as follows. At the beginning of date t, the real return to date $t-1$ to capital is realized, the central bank announces the money growth rate, old agents receive the returns from savings and young agents are endowed with units of the consumption good. Note that the central bank's money growth rate is drawn from the date $t-1$ distribution.[11] Next, the processing fee is made known, and young agents allocate their endowment to consumption, saving,

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

and fed watching. At date t, there is no informational asymmetry. Neither the central bank nor agents, know the random return at the time when the processing fee is set and the fed watching allocation is made. The process repeats at the beginning of date $t+1$. The process then repeats.

The government's problem is to maximize lifetime welfare for the representative young person born at date $t \geq 1$. This is written as

$$\begin{aligned}\bar{W} &= U\left(y - s\left(\rho_t\right) - \rho_t \omega\left(\rho_t\right)\right) \\ &+E\left\{\alpha V\left\{\left[\left(1-\lambda\right)x^h + \frac{\lambda}{\theta}\right]s\left(\rho_t\right) + \lambda s\left(\rho_{t+1}\right)\left(1-\frac{1}{\theta}\right)\right\}\right\} \\ &+E\left\{\left(1-\alpha\right)V\left\{\left[\left(1-\lambda\right)x^l + \frac{\lambda}{\theta}\right]s\left(\rho_t\right) + \lambda s\left(\rho_{t+1}\right)\left(1-\frac{1}{\theta}\right)\right\}\right\}\end{aligned} \tag{9}$$

where the expectation operator applies to the distribution of future money growth rates. I focus on cases in which money does not rate of return dominate capital.

Would the agent be better off, in a welfare sense, if the central bank would become opaque? To answer this question, differentiate equation (9) with respect to the processing fee, yielding

$$\bar{W}_\rho = -U'\left(.\right)\left[s'\left(\rho_t\right) + \omega\left(.\right) + \rho_t \omega'\left(\rho_t\right)\right] \tag{10}$$

$$\begin{aligned}&+E\left\{\alpha V'\left(.\right)\left[\left(1-\lambda\right)x^h + \lambda\right]s'\left(\rho_{t+1}\right)\right\} \\ &+E\left\{\left(1-\alpha\right)V'\left(.\right)\left[\left(1-\lambda\right)x^l + \lambda\right]s'\left(\rho_{t+1}\right)\right\} \\ &+\Delta E\left\{\alpha V\left(.\right) + \left(1-\alpha\right)V\left(.\right)\right\}\end{aligned} \tag{11}$$

Next, evaluate (10) at $\rho_t = \rho_{t+1} = 0$.

Proposition 3 A necessary condition for $\bar{W}_\rho|_{\rho=0} > 0$ is $s'(.) > -1$.

Proof. Recall that $\omega(.)\,|_{\rho=0} = 1$. Note that $\bar{W}_\rho|_{\rho=0} = -U'(.)\left[s'(.)+1\right] + V'(.)\left[(1-\lambda)\bar{x} + \lambda\right]$, where $\bar{x} = \alpha x^h + (1-\alpha)x^l$. The second term is clearly positive. The first term is positive if $s'(.) < -1$. A necessary condition, therefore, for expected lifetime utility to increase in response to central bank opaqueness is that $s'(.) > -1$. ■

Proposition 3 is a local result. Suppose that the central bank is transparent. I derive the conditions in which such a central bank would choose to be opaque. The result indicates the importance of the agent's budget constraint in this analysis. In particular, how an increase in the processing fee–the means of instigating opaqueness, would affect saving. For a young agent, a move to central bank opaqueness shifts some resources toward fed watching, thereby reducing uncertainty. The agent counters by saving less and consuming more when young. Meanwhile, the agent faces greater uncertainty in old age. If the effect of money-growth uncertainty on saving is large enough, the utility increases when young more than offset the explicit cost of fed watching and the marginal utility lost as one introduces more uncertainty into the old-age income.

It is possible to see the key implication associated with intrinsic uncertainty; namely, it introduces an intergenerational conflict. The agent faces uncertainty when old that lowers expected lifetime welfare. In general, saving will change in response to the introduction of intrinsic uncertainty. Suppose the agent saves more in an effort to smooth old-age consumption across the two states.[12] Central bank opaqueness provides a means to offset the effect of the uncertainty, bringing saving closer to the optimal (certain) level. Provided the costs are not too great, the agent benefits from the opaqueness. The intergenerational conflict arises because opaqueness introduces another source of uncertainty to old-age consumption, resulting in further welfare reductions. So, opaqueness may benefit agents when young but unambiguously harms the agent when old. This conflict is the source that makes it possible for

[12] Consider a mean-preserving spread in the distribution of the return to capital. Becuase there is an income and substitution effect, one cannot sign the effect on saving. the key point is that the intrinsic uncertainty results in saving that differs from the level it would in a world with no uncertainty. Let $\hat{s}$ denote savings in the environment in which the central bank is transparent and there is no uncertainty. Let s^* be savings in the world with a transparent central bank and no uncertainty. With the substitution effect dominating, $\hat{s} > s^*$. Throughout the analysis I will focus on this case, though the results are qualitativly the same if the income effect dominates.

opaqueness to raise expected lifetime welfare.

Another interesting feature appears as part of the local result. Notice that the money growth rate does not appear in the expression for $\bar{W}_{\rho}|_{\rho=0}$. In this experiment, there is a mean-preserving spread applied to the distribution of the future money growth as the central bank moves from transparency to opaqueness. So the mean of the distribution appears in the real return to saving, but higher-order moments do not. This is an artifact of the local experiment. Transparency is associated with a degenerate distribution for future money growth rates. Consequently, the higher-order moments are set equal to zero for our experiment. Thus, only the mean value of the future money growth rate affects the decision about whether to be transparent or opaque. This result is somewhat narrower than the reduced-form models in which the variance of the money growth rates affect the central bank's welfare function. Of course, these findings add to the reduced-form structure insofar as saving–a decision rule–affects the central bank's welfare maximizing policy choice.

Equation (10) applies in the global setting. The last term in this expression captures the effects that changes in higher-order moments have on expected lifetime welfare. It is impossible to tell without specific functional forms how the higher-order moments affect the welfare maximizing policy. In addition, it is clear that the more general form of the objective function is necessary for these higher-order moments to affect expected lifetime welfare. In contrast, the reduced-from approach typically uses a quadratic objective function, accounting for why only the mean and variance matter for expected welfare calculations. One implicit advantage of this more general structure is that distributions other than the 2-parameter family are valued. For instance, suppose the central bank chooses a simple state-contingent rule when facing the intrinsic uncertainty; namely, the rule targets the real return to saving. Thus, the distribution of future money growth rates is:

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

This distribution is not normal. Consequently, agents would take higher-order moments into account in their calculations of expected lifetime utility.

Consider the case in which the welfare maximizing policy is $\rho_t > 0$. At some $t > 0$, $\omega_t = 0$ for an economy with $G(\theta)$–the objective distribution function–is time invariant. In words, the intensity of fed watching will vanish over time for an ergodic distribution of the money growth rate. Recall that common knowledge is accumulated with positive amounts of fed watching. Over time, common knowledge renders additional fed watching too costly to undertake. The first-order condition is satisfied with $\omega_t = 0$. Thus, fed watching is valuable to the agent until the agent learns the rule that characterizes the central bank's behavior. I interpret this transition in terms of declining fed watching costs over time. At least in "stable" environments, the costs of opaqueness decline as the agent learns the policy rule. Costs along the transition path, of course, might become greater. Note that capital accumulation is quite trivial in this setup. One interesting extension would be to analyze the continuation costs in a Diamond economy.

6 Concluding remarks

In this paper, I develop a simple overlapping generations model to (i) derive conditions in which an optimizing agent would expend the resources to fed watch; and (ii) show that a central bank, solving a Ramsey problem, would choose to be opaque. For opaqueness to raise lifetime welfare, it must be that the central bank's degree of freedom–the ability to wait and see realizations of the intrinsic random variables–more than offsets the costs of fed watching. Over time, the costs of fed watching are eliminated. In effect, monetary uncertainty is a sufficient statistic for the intrinsic uncertainty that the agent faces. This means that monetary uncertainty does not add any additional long-run costs to the agent's welfare.

In this paper, future money growth rates are uncertain only if the central bank is opaque. A transparent central bank leaves no uncertainty regarding what next-period's money growth rate will be. Opaqueness does not require the agent to solve a noisy signal-extraction problem. Rather, announcements can be made more or less obfuscated, meaning that the agent must spend more resources discerning the content of the announcement. This approach seems consistent with the notion that the central bank is credible and not malicious. In contrast to the noisy signal approach, one is not sure whether the central bank will try to fool agent's or not. I have eliminated the notion of strategic policy signals in this model economy, which seems more in spirit of a benevolent government assumption.

Information in this model in not asymmetric. Nor is there private information. Transparency effectively pins the central bank down to choosing the money growth rate one period in advance. In the absence of any other sources of randomness, I show that transparency is the welfare-maximizing policy. However, with aggregate productivity shocks, there may be advantage to giving the central bank the freedom to observe the shock and choose the welfare-maximizing state-contingent policy. To do so, however, the central bank must be opaque. Interestingly, the effect of the monetary uncertainty on saving is crucial to determining whether central bank opaqueness is welfare maximizing or not. If the effect of monetary uncertainty on saving is large enough, agents would prefer an opaque central bank to a transparent one.

Here, the level of central bank obfuscation can affect the speed at which common knowledge is acquired. I show that the intensity of fed watching is inversely related to the level of obfuscation. In effect, agents rely more heavily on cheaper methods to form expectations about future money growth rates. With less investment in common knowledge, it takes longer for the agent to wean themselves off fed watching. As such, fed watching can easily be quite persistent despite vanishing in the long-run.

The chief contribution of this paper is to integrate opaqueness and fed watching in a model in which the central bank does not have strategic incentives. Here, secrecy–

the strategic transmission of announcement to agents–is not equivalent to opaqueness. Opaqueness is an endogenous outcome, being the solution to the Ramsey problem. At the time that announcements are processed by agents, the central bank does not know anything more about the return to capital than agents do. Insofar as secrecy involves private information, it is difficult to interpret the central bank's date-t behavior as secretive. It is true that with an opaque central bank, 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 3 characterizes an opaque central bank, not a secretive one and it identifies the conditions in which such opaqueness is valuable to the agent.

In a recent paper, Athey, Atkeson, and Kehoe (2001) also identify a tradeoff between opaqueness and transparency. In their setup, the central bank does possess private information. Moreover, there are costs to private agents–in the form of lower expected utility–when the central bank chooses not make its private information public. This paper shares with Athey, Atkeson and Kehoe, the notion of competing costs; privacy is not essential, but the tradeoff is between the explicit resources expended fed watching versus the costs of committing to a transparency.

I view this paper as the first step in a line of research on central bank behavior. Several extensions are worth noting. First, there is an important mechanism design question that is overlooked in this structure. More specifically, the central bank only issues announcements that have positive content in the sense of improving the distribution of future money growth rates. What if the central bank could make noisy announcements? Second, the formation of beliefs is very simple in this setup. It would interesting to see if central bank announcements affect sunspot equilibrium. Lastly, the homogeneous young agent is quite tractable. However, the effects of heterogeneity would be interesting to study.

7 Appendix

Totally differentiate the first-order conditions. The result is

$$\begin{bmatrix} U''(.) + EV''(.)(r_{t+1})^2 & U''(.)\rho_t + \Delta EV'(.) r_{t+1} \\ U''(.)\rho_t + \Delta EV'(.) r_{t+1} & U''(.)\rho_t + \Delta^2 EV(.) \end{bmatrix} \times \begin{bmatrix} \frac{ds_t^*}{d\rho_t} \\ \frac{d\omega_t^*}{d\rho_t} \end{bmatrix}$$

$$= \begin{bmatrix} -U''(.)\,\omega_t^* \\ U'(.) - U''(.)(\rho_t)^2 \end{bmatrix}$$

where ω^* is the intensity of fed watching that satisfies the first-order condition. I evaluate at $\rho_t = 0$. Apply Cramer's Rule, yielding

$$\frac{ds_t^*}{d\rho_t} = \frac{-U''(.)\,J_{22} - U'(.)\,J_{12}}{J_{11}J_{22} - J_{12}J_{21}}$$

Note that $\omega_t^* = 1$ when $\rho_t = 0$. The denominator is positive by the second-order condition. The numerator, however, is negative. Thus, saving is a decreasing function of the processing fee when evaluated at a point in which the central bank is transparent. The response in the intensity of fed watching is

$$\frac{d\omega_t^*}{d\rho_t} = \frac{U'(.)\,J_{11} - J_{21}\left[-U''(.)\right]}{J_{11}J_{22} - J_{12}J_{21}}.$$

With $J_{11} < 0$ and $J_{21} > 0$ evaluated at $\rho_t = 0$, the numerator is less than zero.

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