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IMCOMPLETE INFORMATION, MONOPOLISTIC COMPETITION AND MACROECONOMICS: EXTERNALITY IN INFORMATION ACQUISITION AND THE NON-NEUTRALITY OF MONEY

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ABSTRACT

This paper constructs a macroeconomic model where firms do not find it individually worthwhile to obtain (costly) information about monetary disturbances, but the economy as a whole would be better off if firms all paid for and obtained the information. The reason is that firms acquiring the information provide a positive externality to consumers, who dislike fluctuations in consumption and leisure, because firms' price adjustment stabilizes output. A very small cost of information acquisition is sufficient to cause non-neutrality of monetary disturbances in a monopolistically competitive economy where otherwise money is neutral.

1. INTRODUCTION

The purpose of this paper is to construct a macroeconomic model in which firms do not find it individually worthwhile to obtain (costly) information about monetary disturbances, but the economy as a whole would be better off if firms all paid for and obtained the information. The reason is that firms that do acquire the information provide a positive externality to consumers, who dislike fluctuations in consumption and leisure, because firms' price adjustment stabilizes output.

If firms acquire information about monetary disturbances, then their prices are perfectly flexible with respect to the disturbances. Thus, real balances are stabilized, so that output is stabilized. Output stabilization increases the utility of consumers, because it reduces fluctuations in consumption and work hours. Consequently, there is a substantial social gain from acquiring the information. However, when a firm considers whether to acquire information or not, it does not take into consideration this social gain from acquiring the information. Real balances depend on the general price level, which is beyond the control of one firm. Because the firm cannot influence real balances, it ignores the gain from stabilizing real balances in its calculation of the private gain from acquiring the information. Thus, there is an externality in acquiring information, which makes the private and social gains form acquiring the information diverge.

If a firm acquires information about monetary disturbances, it can reduce forecast errors about the general price level. Then its profits are increased through reducing the possibility of suboptimal production caused by forecast errors. This increase in profits is the private gain from acquiring information.

We further argue in this paper that the private gain from acquiring information about monetary disturbances may be small under plausible assumptions in a monopolistically competitive macroeconomic model similar to Weitzman (1985) and Blanchard and Kiyotaki (1987). We show that if (1) consumers' utility functions are sufficiently concave in consumption and leisure, and (2) firms' technology exhibits constant returns to scale, then the private gain from acquiring information about monetary disturbances is negligible while the social gain is substantial. We obtain this result under the assumption that real wages are predetermined (nominal wages are perfectly indexed to the price level) and that firms are given the right to determine employment, although the same result is obtained under the predetermined nominal wage assumption. The reason we make the predetermined real wage assumption is that monetary disturbances are neutral under the predetermined real wage if all firms acquire information. Thus, the externality in information acquisition is capable of inducing non-neutrality of monetary disturbances in a monopolistically competitive economy where otherwise money is neutral.

The private gain from acquiring information depends on (a) the predictability of the price level, and (b) the loss due to forecast errors. Imperfect and noisy information about monetary disturbances implies sticky prices, because the firm is aware of the possibility of confusing local, firm-specific shocks as global, macroeconomic shocks. These sticky prices in turn means the general price level is more predictable in this case than in the case of flexible prices. This reduces the private gain from acquiring information. Moreover, the loss due to forecast errors is smaller under constant marginal costs than under increasing marginal costs, which further reduces the private gain. In fact, it will be shown that the price level under our assumptions becomes constant (that is, completely rigid with respect to monetary disturbances) and perfectly predictable even though firms do not acquire information about monetary disturbances. Then, firms does not at all gain from acquiring information about monetary disturbances. In this case, a very small cost of acquiring the information is sufficient in preventing firms from acquiring the information. Thus, firms rationally choose to be imperfectly informed about monetary disturbances.

The social gain is, however, large, because (i) prices are rigid, which implies large fluctuations in consumption and leisure, and (ii) consumers dislike fluctuations in consumption and leisure. The economy ends up in a situation where insufficient information is built into price formation as seen from the viewpoint of a social planner.

The argument in this paper is closely related to the "small menu cost" approach to price rigidity (Akerlof and Yellen (1985), and Blanchard and Kiyotaki (1987)). Just as it is possible to show that small menu costs of price adjustment may lead to large output movements due to price stickiness, it can also be shown that small costs of acquiring information may lead to large output fluctuations due to incomplete information. In both cases the argument hinges on an externality that drives a wedge between the private and social costs of changing prices (in the one case) and acquiring information (in the other).

The point made in this paper is important for macroeconomics. A common criticism of Lucas (1973) and similar perfectly competitive models based on imperfect information about the money supply is that producers could obtain the information at fairly low costs. If the gains from doing so were large, then they would obtain the information. The result of this paper shows that this need not be the case: the private gains from information acquisition may be small but the positive external effect is large in the monopolistically competitive economy.

The information acquisition externality is also capable of resolving another problem in the imperfect information perfectly competitive models. These models have the property that only unanticipated monetary disturbances influence the real economy. However, many empirical results show that not only unanticipated but also anticipated monetary shocks affect output.[1] In addition, the imperfect information perfectly competitive models cannot explain the persistence of output movement found in time series data without additional assumptions, because unanticipated shocks are not autocorrelated. The result of this paper shows that monetary disturbances are not neutral because economic agents do not acquire information about them. In this case, all monetary shocks are unanticipated even if information about them is made public. Monetary disturbances have persistent effects on the economy so long as they are autocorrelated.

The plan of this paper is as follows. In section 2, a simple general equilibrium macroeconomic model of a monopolistically competitive economy under incomplete information is presented. Section 3 contains the major result of this paper, in which the social gain from information acquisition and the private gain are defined and calculated under the assumption of constant returns to scale. Section 4 concludes the paper.

2. A MACROECONOMIC MODEL OF MONOPOLISTIC COMPETITION AND INCOMPLETE INFORMATION

The Model

The model in this paper is closely related to those of Weitzman (1985) and Blanchard and Kiyotaki (1987). The novel feature of this model is the introduction of disturbances in the money supply and preferences of the consumer.

The economy consists of one representative consumer and n firms. Each firm produces a specific good that is an imperfect substitute for the other goods. Because products are differentiated, each firm has some monopoly power in product markets. Thus, product markets are imperfectly competitive. Firms use labor inputs supplied by the consumer, and pay wages and dividends to the consumer. Firms do not retain profits.

As for labor markets, we assume exogenous real wages. It is assumed that (1) the real wage is constant (through full indexation of the nominal wage to the price level), and (2) firms are given the right to determine employment. Suppose that, like Fischer (1977) and Gray (1976), the labor market is competitive, but assume that (a) the labor market is opened before the realization of monetary and preference shocks, and (b) the real wage is determined there (that is, nominal wage determined in the labor market is, implicitly or explicitly, fully indexed to the price level).[2] This exogenous real wage assumption is made, partly because it is a convenient short-cut to describe at least the non-unionized part of the United States economy, where (i) there is no systematic relationship between real wages and output[3] and (ii) firms determine employment, and partly because monetary disturbances are neutral under the exogenous real wage assumption if all firms acquire information about monetary disturbances and are perfectly informed about them. (The argument developed in this paper, that firms rationally choose to be imperfectly informed about monetary disturbances, holds true for the case of exogenous nominal wages, but in this case monetary disturbances is not neutral in a trivial sense.) The firm maximizes its real profits, taking the real wage as given.

The consumer derives utility from consumption of goods, liquidity services of real money balances, and leisure. He gets initial money balances through transfer payments from the government, and receives wages and dividends from firms. He maximizes his utility by choosing consumption of goods and money balances, taking prices as given. Note that under the exogenous real wage assumption made earlier, work hours (leisure) are determined by firms.

<u>The Sequence of Events</u>

Before presenting detail of the model, it is worthwhile to specify the sequence of events in this model. There are two stages: the first is the consumption decision stage, and the second is the price decision stage.

At the beginning of the first stage, the nature chooses the particular realization of monetary and preference disturbances. Then the government allocates money to the consumer through transfer payments. The consumer knows the structure of the economy, and observes all the disturbances. Because he is perfectly informed about the economy, the consumer can correctly infer prices that firms will charge, and wages and dividends that he will receive at the second stage. He determines consumption and real money holdings, taking prices, wages, dividends, and initial money holdings as given. At the end of the first stage, the money market is opened, and monetary equilibrium is achieved.

Firms know the structure of the economy except for the realization of monetary and preference disturbances. At the beginning of the second stage, firms get information Ω_i. Ω_i is imperfect information about monetary and preference disturbances. (Informational exchange between firms and the consumer is assumed to be prohibited.) Firms simultaneously choose their prices, based on Ω_i. The second stage is an incomplete-information game in the sense of Harsanyi. After all prices are determined, the consumer actually purchases goods from firms and consumes them, and firms pay wages and dividends to the consumer.

Symmetry

Firms are assumed to be symmetric in that they have the same functional form of demand and production functions, except for demand disturbances (which are determined by preference disturbances). These symmetric assumptions enable us to simplify welfare analysis.

(1) The First Stage: Consumption Decision and Monetary Equilibrium

Because (1) the first stage is the consumption decision stage and (2) the consumer has perfect information about the economy, we can analyze the consumption behavior and the equilibrium in the money market, assuming that the consumer knows prices that firms will charge at the second stage.

The Representative Consumer

The representative consumer derives utility from consumption, real money balances, and leisure. His utility function Ψ is the composite of the CES and Cobb-Douglas functions such that

$$(1\ )\quad \Psi \equiv \frac{1}{1-z}\left[D(n\bar{Y})^{\zeta}\left(\frac{\tilde{M}}{\bar{P}}\right)^{1-\zeta}\right]^{1-z} - \left(\Sigma_{i=1}^{n} L_i\right)^{\mu},$$

where D is a normalization factor such that $D = \zeta^{-\zeta}(1-\zeta)^{-(1-\zeta)}$, n is the number of goods (and the number of firms), $\bar{Y}$ is the average consumption index defined below, $\tilde{M}$ is the end-of-the-period nominal money holdings, and $\bar{P}$ is the price level. ζ is a parameter which satisfies $0 < \zeta < 1$. Real balances $\tilde{M}/\bar{P}$ is in the utility function, because real balances yield liquidity services. L_i is the labor supply to the i-th firm, and $\Sigma_{i=1}^{n} L_i$ is the total work hours of the representative consumer. Thus, $(\Sigma_{i=1} L_i)$ represents the disutility of labor. We assume that $1 < \mu$.

The term z in (1) represents the degree of the consumer's "consumption risk aversion" with respect to the composite of the average consumption index and real balances, $D(n\bar{Y})^{\zeta} (\tilde{M}/\bar{P})^{1-\zeta}$, which is hereafter called the consumption composite. If $z > 0$, the consumer dislikes fluctuations in the consumption composite. We assume $z > 1$, so that the consumer is sufficiently consumption risk averse.

The average consumption index $\bar{Y}$ is defined as follows:

$$(2)\ \bar{Y} = \bar{Y}(\{Q_i\}:_{i = 1,\dots,n}) \equiv (\Sigma_{i=1}^{n} U_i^{1/k} Q_i^{(k-1)/k})/n\}^{k/(k-1)},$$

where Q_i is the consumption the i-th product. The parameter k satisfies $1 < k$. (This assumption is necessary for profit maximization of firms which will be specified later in this section.)

U_i represents the <u>product-specific</u> preference disturbance. We assume that U_i is a draw from a log-normal distribution, that is, $\log U_i$ is a draw from a normal distribution with mean zero and variance σ_u^2.

$\bar{P}$ is defined as the price level function associated with the average consumption index function $\bar{Y}$:

$$(3)\ \bar{P} = \bar{P}(\{P_i\}:_{i = 1,\dots,n}) \equiv \{(\Sigma_{i=1}^{n} U_i P_i^{1-k})/n\}^{1/(1-k)},$$

where P_i is the price of the i-th product.

The consumer's demand for each product and the demand for real balances are derived from the maximization of Ψ with respect to Q_i and $\tilde{M}/\bar{P}$ subject to the following budget constraint:

(4) $\Sigma_{i=1}^{n} P_i Q_i + \tilde{M} = B,$

where B is the beginning-of-the-period asset of the consumer.

Let us now consider B. The consumer obtains (a) money from the government as transfer payments, and (b) wage payments and dividends from firms. We have assumed that (1) the real wage is constant and the same for all firms, and (2) firms are given the right to determine employment. For notational simplicity, the real wage is assumed to be unity. Then, B is such that

$$B = \Sigma_{i=1}^{n} (\bar{P}L_i + \Pi_i) + M,$$

where $\bar{P}L_i$ is the wage payment of the i-th firm, and Π_i is dividends from the i-th firm. The beginning-of-the-period money holdings is equal to the money supply, M.

The money supply is a random variable. We assume that M is a draw from a log-normal distribution, that is, logM is a draw from a normal distribution with mean zero and variance σ_m^2. logM and $\log U_i$ are independent.

<u>Demand Functions and Monetary Equilibrium</u>

Using the property of the CES and Cobb-Douglas functions, we can derive the demand Q_i for the i-th product and the demand for real balances $\tilde{M}/\bar{P}$. They are

(5) $Q_i = (\frac{P_i}{\bar{P}})^{-k} \bar{Y} U_i$, where $n\bar{Y} = \zeta\frac{B}{\bar{P}}$, and $\frac{\tilde{M}}{\bar{P}} = (1 - \zeta)\frac{B}{\bar{P}}$.

In order that the economy is in monetary equilibrium at the first stage, the money demand should be equal to the money supply. Thus, the end-of-the-period money holdings should be equal to the beginning-of-the-period money holdings. That is,

$$(6)\quad \tilde{M} = M$$

should be satisfied. Because of (5) and (6), we obtain from the monetary equilibrium condition

$$(7)\quad \bar{Y} = H_1 \frac{M}{\bar{P}}, \text{ where } H_1 = \frac{\zeta}{1-\zeta}\frac{1}{n}.$$

Thus, in equilibrium, the average demand is proportional to initial real money holdings.

<u>The Consumer's Utility in Equilibrium</u>

Substituting demand functions (5) and (7) into (1), we obtain the consumer's utility in equilibrium such that

$$(8)\quad \Psi \equiv \frac{1}{1-z}\left[\frac{B}{\bar{P}}\right]^{1-z} - (\Sigma_i L_i)^{\mu} = \frac{1}{1-z}\left[\frac{n}{\zeta}\cdot\bar{Y}\right]^{1-z} - (\Sigma_{i=1}^{n} L_i)^{\mu},$$

where L_i is determined by firms in the second stage.

(2) The Second Stage: Price Decision and Incomplete Information Game

<u>Firms' Payoff Function</u>

Firms are indexed by i, i = 1, ..., n. The demand for the i-th firm's product, Q_i, is from (5) and (7)

$$(9)\quad Q_i = \left(\frac{P_i}{\bar{P}}\right)^{-k} \bar{Y}U_i = H_1\left(\frac{P_i}{\bar{P}}\right)^{-k}\left(\frac{A_i}{\bar{P}}\right), \text{ where } A_i = MU_i.$$

In order to produce output Q_i, the i-th firm needs labor inputs. We assume

$$(10)\quad L_i = GQ_i^{1+c_1},$$

where L_i is labor inputs, and $c_1 \geq 0$. Thus, we assume non-increasing returns to scale. G is a normalization factor such that

$$(11)\qquad G = \frac{k-1}{(1+c_1)k} \exp[\{1 + c_1(k - 1)\}z(\frac{c_1}{1+c_1 k})\sigma_u^2],$$

where

$$(12)\qquad z(x) = \frac{\{1 - (k - 1)x\}^2}{2\,(k - 1)}.$$

(This normalization simplifies the expression of the equilibrium price level derived later.)

The i-th firm's profit Π_i is

$$(13)\quad \Pi_i = P_iQ_i - \bar{P}L_i = P_iQ_i - \bar{P}GQ_i^{1+c_1},$$

because the real wage is unity.

The i-th firm maximizes the <u>real profit</u>. From (9), and (13), the firm's payoff function is

(14) $\frac{\Pi_i}{\bar{P}} = \Upsilon(P_i, \bar{P}, A_i) \equiv H_1\left(\frac{P_i}{\bar{P}}\right)^{1-k} \frac{A_i}{\bar{P}} - G\{H_1\left(\frac{P_i}{\bar{P}}\right)^{-k} \frac{A_i}{\bar{P}}\}$.

The Monopolistically Competitive Assumption in the Strong Form

Throughout this paper, we make the following strong form of a monopolistically competitive assumption. We assume that the number of firms (and the number of goods), n, is so large that the dependence of the price index $\bar{P}(\{P_i\})$ on particular P_i is negligible. This implies that the firm ignores the dependence of $\bar{P}$ on its own price P_i, in determining its price. Thus, the firm takes $\bar{P}$ as given under this strong form of a monopolistically competitive assumption.

The Incomplete Information Game

At the beginning of the second period, the firm gets information about M and U_i. Let Ω_i be the information that the firm receives. We consider two cases.

(I) NO MONETARY INFORMATION: $\Omega_i = A_i$. The firm can observe $A_i = MU_i$, but M and U_i are not independently observed. In this case, $\Omega_i = A_i$.

(II) MONETARY INFORMATION: $\Omega_i = \{M, U_i\}$. The firm can observe M as well as A_i. In this case, the firm can correctly infer U_i using the relation $A_i = MU_i$. Thus, $\Omega_i = \{M, U_i\}$ in the second case.

The firm's strategy is the price. The firm's strategy depends on information Ω_i. Under the monopolistically competitive assumption in the strong form, the Bayesian Nash equilibrium of the incomplete information game is defined as the set of policy functions $\{\phi_i(\Omega_i)\}_{i=1,\ldots,n}$, such that for all i = 1,...,n, $M \in [0, \infty)$, and $U_i \in [0, \infty)$,

$$E\left[\Upsilon\left[\Phi_i(\Omega_i),\ \bar{P}(\{\Phi_s(\Omega_s)\}),\ A_i\right]\middle|\Omega_i\right] \geq E\left[\Upsilon\left[P_i,\ \bar{P}(\{\Phi_s(\Omega_s)\}),\ A_i\right]\middle|\Omega_i\right].$$

is satisfied for all $P_i \in [0, \infty)$. Note that the price index $\bar{P}(\{P_s\}:_{s = 1,\dots,n})$ is defined in (3).

<u>Two Simplifying Assumptions</u>

To simplify the analysis, we make two additional assumptions. (1) We consider the symmetric equilibrium. That is, we assume that, if $\Omega_i = \Omega_j = \Omega$, then we have $\Phi_i(\Omega) = \Phi_j(\Omega) = \Phi(\Omega)$. (2) We restrict our attention to the case of log-linear policy functions. Thus, we assume $\Phi(\Omega_i) = \Theta\cdot A_i^{\rho}$ for some real numbers Θ and ρ in the case of no monetary information in which $\Omega_i = A_i$, while we assume $\Phi(\Omega_i) = \Phi\cdot M^{\delta}U_i^{\lambda}$ for some real numbers Φ, δ, and λ in the case of monetary information in which $\Omega_i = \{M, U_i\}$.

The monopolistically competitive assumption in the strong form, together with the symmetric and log linear policy assumptions simplifies the expression of the price index.[4] Let us define the following price-index function:

$$(15)\ \bar{P}^*(M, \Phi, \delta, \lambda) \equiv \Phi\cdot M^{\delta}\cdot\exp[-\ z(\lambda)\sigma_u^{\ 2}],$$

where $z(\lambda)$ is defined in (12). Then, the price level in the case of no monetary information is

$$(16)\ \bar{P}(\Phi(A_s):_{s=1,\dots,n}) = \bar{P}^*(M, \Theta, \rho, \rho).$$

while the price level in the case that monetary information is freely available is

(17) $\bar{P}(\Phi(M, U_s):_{s=1,\dots,n}) = \bar{P}^*(M, \Phi, \delta, \lambda)$.

The Symmetric, Log-linear Policy, Monopolistically Competitive Bayesian Nash Equilibrium

Under the above assumptions, the symmetric Bayesian Nash equilibrium of the incomplete information game is defined in the following way.

(I) NO MONETARY INFORMATION $\Omega_i = A_i$. The symmetric Bayesian Nash equilibrium is a policy function $\Phi(A_i) = \Theta \cdot A_i^{\rho}$ such that

$$(18)\quad E\left[\Upsilon\left[\Phi(A_i),\ \bar{P}^*(M, \Theta, \rho, \rho),\ A_i\right] \Big| A_i\right]$$

$$= \max_{P_i \in [0,\infty)} E\left[\Upsilon\left[P_i,\ \bar{P}^*(M, \Theta, \rho, \rho),\ A_i\right] \Big| A_i\right].$$

for all $M \in [0, \infty)$, and $U_i \in [0, \infty)$, where $A_i = MU_i$.

(II) MONETARY INFORMATION $\Omega_i = \{M, U_i\}$. Note that under the assumptions made earlier, there is no uncertainty about the real profit, because the firm can correctly infer $\bar{P}^*(M, \Phi, \delta, \lambda)$ since M is observable. Thus, the symmetric Nash equilibrium is a policy function $\Phi(M, U_i) = \Phi \cdot M^{\delta} U_i^{\lambda}$ such that

$$(19)\quad \Upsilon\left[\Phi(M, U_i),\ \bar{P}^*(M, \Phi, \delta, \lambda),\ A_i\right] = \max_{P_i \in [0,\infty)} \Upsilon\left[P_i,\ \bar{P}^*(M, \Phi, \delta, \lambda),\ A_i\right].$$

3. COORDINATED INFORMATION ACQUISITION VS. NON-COOPERATIVE INFORMATION ACQUISITION

Costly Information Acquisition about the Money Supply

Suppose that monetary information is initially not available. Thus, firms play the incomplete information game with no monetary information. Now an government agency announces the money supply M at the end of the first stage. However, we assume that in order to use this information in the second stage, the firm has to pay the information cost before the nature chooses M and U_i (that is, before the beginning of the first period). The firm has to commit in advance to constantly monitoring the money supply figure, in order to utilize the money supply information. We assume that to monitor the money supply constantly needs F units of labor inputs. Because the real wage is assumed to be unity, F is also the real information cost for the firm in the form of the real wage payment for such monitoring activities.

We compare the following two cases. The first case is coordinated information acquisition. In this case, all firms agree to incur the information cost F. The second case is non-cooperative information acquisition. In the latter case, information acquisition becomes a game. We consider the symmetric equilibrium of the following information acquisition game. At the first stage, firms simultaneously determine whether to incur F in order to constantly monitor the money supply. At the second stage, the nature chooses M and U_i. At the third stage, the i-th firm observes A_i. If the firm incurred F at the first stage, it obtains perfect information about M at the third stage, so that its information is $\Omega_i = \{M, U_i\}$. If it did not incur F at the first stage, its information is $\Omega_i = A_i$ at the third stage. At the fourth stage, all firms simultaneously choose P_i.

The Net Social Gain from Information Acquisition

The net social gain from information acquisition is defined as the difference in the unconditional expected utility of the representative consumer between coordinated information acquisition and no information acquisition. If all firms acquire information, we have $\Omega_i = \{M, U_i\}$ for all i. If no firm acquires information, we get $\Omega_i = A_i$ for all i. Thus, the net social gain NSG from information acquisition is from (8)

$$(20)\quad NSG = E_{M,U_i}\left[\frac{1}{1-z}\left[\frac{n}{\zeta}\cdot\bar{Y}\right]^{1-z} - (\Sigma_{i=1}^{n}L_i + nF)^{\mu}\right]\Big|\Omega_i=\{M, U_i\}$$

$$- E_{M,U_i}\left[\frac{1}{1-z}\left[\frac{n}{\zeta}\cdot\bar{Y}\right]^{1-z} - (\Sigma_{i=1}^{n}L_i)^{\mu}\right]\Big|\Omega_i=A_i.$$

Thus, if NSG > 0, then to acquire information about the money supply is socially desirable.

<u>The Net Private Gain from Information Acquisition</u>

In order to acquire monetary information, the firm has to hire workers who constantly monitor the movement of the money supply. Thus, the cost of information acquisition for the firm is the additional wage payment to these workers, which is equal to F since the real wage is unity.

The net private gain from information acquisition is defined as the difference in the unconditional expected payoff of the firm[5] between (1) the case in which only this firm incurs F (and thus has perfect information about M) <u>while the other firms do not incur F</u> (and do not know M), and (2) the case where all firms do not incur F (and do not know M). Under the monopolistically competitive assumption in the strong form, the price level does not depend on this firm's price. Thus, the price level in both cases is the same as that in the case of no monetary information. However, if this firm incurs F, it has perfect information about M as well as A_i. Thus, the net private gain NPG from information acquisition is

$$\text{(21)} \qquad NPG = \{E_{M,U_i} \Upsilon(P_i, \bar{P}, A_i)\big|_{\Omega_i=\{M,\ U_i\},\Omega_j=A_{j:j\neq i}} - F\}$$

$$- \{E_{M,U_i} \Upsilon(P_i, \bar{P}, A_i)\big|_{\Omega_i=A_i}\}.$$

If NPG < 0, then no information acquisition is Nash equilibrium of the information acquisition game described earlier.

<u>Is a Small Cost of Monitoring Sufficient to Cause Insufficient Information Acquisition?</u>

We are concerned with the case in which (1) the gross private gain from acquiring information, $E_{M,U_i}\Upsilon\big|_{\Omega_i=\{M,\ U_i\},\Omega_j=A_{j:j\neq i}} - E_{M,U_i}\Upsilon\big|_{\Omega_i=A_i}$, is very small, so that a very small cost F of constantly monitoring the money supply figure is sufficient to prevent firms from incurring the information cost (NPG is negative), while (2) the net social gain from acquiring information, NSG, is substantial. Information is insufficiently acquired in such an economy.

In the following, we investigate whether macroeconomic equilibrium is characterized by insufficient information acquisition under plausible conditions. Our answer is affirmative. We show that if firms' production technology exhibits constant returns to scale, then the private gain is zero in the monopolistically competitive macroeconomic model of the previous section, so that a very small cost of monitoring the money supply figure is sufficient to prevent firms from acquiring the money supply information. However, the resulting fluctuation in the average consumption index lowers the representative consumer's utility, and thus there is a large social gain from acquiring information.

The Case of Constant Returns to Scale

Suppose that firms' technology exhibits constant returns to scale, so that $c_1 = 0$. In this case, we have from (14)

$$(22)\ \Upsilon(P_i, \bar{P}, A_i) = H_1\left(\frac{P_i}{\bar{P}}\right)^{1-k}\frac{A_i}{\bar{P}} - GH_1\left(\frac{P_i}{\bar{P}}\right)^{-k}\frac{A_i}{\bar{P}}.$$

The Net Social Gain from Information Acquisition under Constant Returns to Scale

In order to calculate the net social gain, we first have to find the Bayesian Nash equilibrium of (I) the case of no monetary information and (II) the case of monetary information.

(I): NO MONETARY INFORMATION $\Omega_i = A_i$. If technology is subject to constant returns to scale and there is no monetary information, prices become completely rigid with respect to the monetary disturbance as well as the product-specific disturbances. To see this, recall that the policy function has the form of $P_i = \Theta A_i^{\rho}$. We show that $\Theta = H_1$ and $\rho = 0$ are Bayesian Nash equilibrium.

From (22), (16), and the equilibrium definition (18), we obtain the equilibrium condition such that

$$(23)\ P_i = \frac{k}{k-1}G\frac{E[(\bar{P}^*(M, \Theta, \rho, \rho))^{k-1}|A_i]}{E[(\bar{P}^*(M, \Theta, \rho, \rho))^{k-2}|A_i]}.$$

Because M is log-normally distributed, $\bar{P}^*(M, \Theta, \rho, \rho)$ is also log-normally distributed. Consequently, we obtain

$$(24)\ P_i = \frac{k}{k-1} G \cdot E[\bar{P}^*(M, \Theta, \rho, \rho)|A_i] \exp\left[\frac{1}{2}\{(k-1)^2 - (k-2)^2\} V[\bar{P}^*(M, \Theta, \rho, \rho)|A_i]\right].$$

It is easy to show that $P_i = H_1$ satisfies the above expression, because we have (a) $G = \{(k - 1)/k\}\exp[z(0)\sigma_u^2]$ from (11) in the case of constant returns to scale ($c_1 = 0$), and (b) $\bar{P}^*(M, H_1, 0, 0) = H_1 \cdot \exp[- z(0)\sigma_u^2]$ from (15).

The complete rigidity of the price index can be explained in the following way. The equilibrium condition (24) implies that the firm's optimal price should be exactly as elastic to the change in M as the expected price conditional on A_i. However, this is not possible if P_i is sensitive to A_i, that is, $\rho > 0$. Because of the possibility of local-global confusion, one percent change in A_i due to the change in M induces only less than one percent change in the expectation of M conditional on $A_i = MU_i$. Consequently, if $\rho > 0$, one percent change in M would induce ρ percent change in P_i, whereas this would induce less than ρ percent change in the expected price index conditional on A_i, which violates the equilibrium condition. Thus, we have $\rho = 0$ in equilibrium.

Because prices are completely rigid, the monetary disturbance is absorbed by the fluctuation in the average consumption index in this equilibrium. From (7), we have

$$(25)\ \bar{Y}\Big|_{\Omega_i = A_i} = M \cdot \exp[z(0)\sigma_u^2]$$

in the case of no monetary information. The average consumption index fully reflects the change in the money supply.

(II) MONETARY INFORMATION $\Omega_i = \{M, U_i\}$. By contrast, if firms use monetary information, prices become completely flexible with respect to the monetary disturbance, although they are rigid with respect to the product-specific disturbances. In this case, the policy function has the form $P_i = \Phi M^\delta U_i^\lambda$. From (22) and the equilibrium definition (19), we obtain the equilibrium condition such that

$$(26) \qquad P_i = \frac{k}{k-1} G\bar{P}^*(M, \Phi, \delta, \lambda).$$

It is fairly straightforward to show that $\Phi = H_1$, $\delta = 1$, and $\lambda = 0$ satisfy the above equation, because $G = \{(k - 1)/k\}\exp[z(0)\sigma_u^2]$ and $\bar{P}(M, H_1, 1, 0) = H_1 M \cdot \exp[- z(0)\sigma_u^2]$. Consequently, they constitute Nash equilibrium.

Since prices are completely flexible with respect to the monetary disturbance, the average consumption index is insulated from the monetary disturbance. We have

$$(27) \quad \bar{Y}\big|_{\Omega_i=\{M,\ U_i\}} = \exp[z(0)\sigma_u^2]$$

Let us now consider the utility of the representative consumer. We will analyze it in the following way. We will first show that the representative consumer's utility Ψ (ignoring the disutility nF of information acquiring activities) depends solely on the log of the average consumption index, $\log\bar{Y}$. Then, it will be shown that the consumer's utility is strictly concave in $\log\bar{Y}$. Using (25) and (27), we will show that $\log\bar{Y}$ in the case of no information acquisition is a mean preserving spread of $\log\bar{Y}$ in the case of coordinated information acquisition. The representative consumer's utility (ignoring the disutility of nF of information acquiring activities) will be shown to be unambiguously higher in the case of coordinated information acquisition than in the case of no information acquisition. Thus, so long as nF is small, there will be a substantial positive net social gain.

Because we have from (9)

$$L_i = GQ_i = G\left(\frac{P_i}{\bar{P}}\right)^{-k} \bar{Y}U_i$$

under constant returns to scale, we obtain from (8), ignoring the disutility of information acquiring activities,

$$\Psi = \frac{1}{1 - z}\left[\frac{n}{\zeta}\cdot\bar{Y}\right]^{1-z} - \left[\bar{Y}\right]^{\mu}\cdot\left[G\Sigma_{i=1}^{n}\left(\frac{P_i}{\bar{P}}\right)^{-k} U_i\right]^{\mu}.$$

Note that we have $P_i/\bar{P} = \exp[z(0)\sigma_u^2]$ in the case of no monetary information, because $P_i = H_1$ is its Bayesian Nash equilibrium. Similarly, we have $P_i/\bar{P} = \exp[z(0)\sigma_u^2]$ in the case of monetary information, because $P_i = H_1M$ is its Nash equilibrium. Consequently, we obtain

$$\Psi = \frac{1}{1 - z}\left[\frac{n}{\zeta}\cdot\bar{Y}\right]^{1-z} - \left[\bar{Y}\right]^{\mu}\cdot Z$$

regardless of $\Omega_i = A_i$ or $\Omega_i = \{M, U_i\}$, where Z is a constant such that

$$Z = \{Gn\}^{\mu}\exp[- \mu kz(0)\sigma_u^2]\left[\frac{1}{n}\Sigma_{i=1}^{n}U_i\right]^{\mu} = \{Gn\}^{\mu}\exp[\mu\{- kz(0) + (1/2)\}\sigma_u^2].$$

Here the law of large numbers is employed for U_i. Thus, we get the representative consumer's utility in the log form:

From (28), the second derivative of Ψ with respect to $\log\bar{Y}$ is

$$(29)\quad \partial^2\Psi/\partial(\log\bar{Y})^2 = (1 - z)\exp[(1 - z)\log(\tfrac{\eta}{\zeta}) + (1-z)\log\bar{Y}] - \mu^2\exp[\mu\log\bar{Y}]\cdot Z,$$

which is negative so long as $\mu > 1$ and $z > 1$. Thus, the representative consumer dislikes fluctuations in the log of the aggregate consumption index, $\log\bar{Y}$.

Note that $\log\bar{Y} = \log H_1 + \log M - \log\bar{P}$. On the one hand, because prices become completely sticky in the case that all firms do not acquire monetary information, we have $\log\bar{Y} = \log M + z(0)\sigma_u^{\,2}$ from (25), a fluctuating average consumption index. On the other hand, if all firms acquire monetary information, the price level is perfectly flexible with respect to the money supply, so that we get a completely stable average consumption index, $\log\bar{Y} = + z(0)\sigma_u^{\,2}$ from (27). This implies that the average consumption index in the case of no information acquisition is a mean-preserving spread of the average consumption index in the case of coordinated information acquisition, because $E(\log M) = 0$ and $V(\log M) = \sigma_m^{\,2}$. Consequently, the representative consumer's utility (excluding the disutility of information acquiring activities) is higher in coordinated information acquisition than in no information acquisition. Thus, there is a positive net social gain from acquiring information through the stabilization of the average consumption index, so long as the disutility of information acquiring activities is small.

<u>The Net Private Gain from Information Acquisition under Constant Returns to Scale</u>

Next consider the net private gain from information acquisition under constant returns to scale. Recall that the net private gain is the difference in the unconditional expected payoff of the firm between (1) the case in which only this firm incurs F (and thus has perfect information about M) while the other firms do not incur F (and do not know M), and (2) the case where all firms do not incur F (and do not know M).

Under constant returns to scale, the firm's payoff ignoring the cost of information acquisition is from (22) and (9)

$$\Upsilon(P_i, \bar{P}, \bar{Y}U_i) = \{(\frac{P_i}{\bar{P}})^{1-k} - G(\frac{P_i}{\bar{P}})^{-k}\}\bar{Y}U_i.$$

Because the price level does not depend on the firm's price under the monopolistically competitive assumption in the strong form, the firm cannot influence the average demand $\bar{Y}$. Consequently, the private gain from acquiring information is the gain from reducing suboptimal production (due to forecast errors) through improved forecast of the price level. However, as explained earlier, if the other firms do not acquire information, the price level is constant and completely insensitive to the money supply. In this case, the firm can correctly infer the price level when the firm does not have any information about the money supply. Thus, even if the firm obtains information about the money supply, this information is redundant in estimating the price level. Then, information about the money supply has no value for the firm if other firms do not acquire information about the money supply. Consequently, the private gain from acquiring information is zero under constant returns to scale.

Insufficient Information Acquisition under Constant Returns to Scale

Suppose that (1) the variance of logM is large, and (2) to acquire money supply information needs a very small labor input F. Then, nF in (20) is negligible. The foregoing argument about the net social gain shows that the net social gain is substantial in this case, so that to acquire money supply information is socially desirable. However, because the private gain is zero, no information acquisition is Nash equilibrium of non-cooperative information acquisition. Consequently, the economy suffers from insufficient information acquisition of firms.

4. CONCLUDING REMARKS

We have shown in this paper that if (1) consumers' utility functions are sufficiently concave in consumption and leisure ($z > 1$ and $\mu > 1$), and (2) firms' technology exhibits constant returns to scale ($c_1 = 0$), then the net private gain from acquiring information about monetary disturbances is negative while the net social gain is substantial in a monopolistically competitive economy where (3) real wages are exogenously given (nominal wages are perfectly indexed to the price level) and firms determine their employment. In this economy, monetary disturbances have real effects on output, because firms choose not to acquire information about them. However, output fluctuations reduce the social welfare.

The argument of this paper depends on the three assumptions mentioned above. We briefly discuss the effect of possible relaxation of them.

The assumption that $z > 1$ can be relaxed without changing qualitative results of this paper, so long as μ is sufficiently large. This is evident from (29), in which Ψ is concave in $\log\bar{Y}$ even in the case that $1 > z$ if the second term dominates the first term. A large μ implies a large absolute value of the second term.

The constant-returns-to-scale assumption can also be relaxed without changing qualitative results, so long as the degree of decreasing returns to scale, c_1, is not large. APPENDIX presents the Bayesian Nash equilibrium of the case of no monetary information and the case that monetary information is available. It is shown there that the sensitivity of the price level to monetary disturbances is small in the case of no monetary information if c_1 is small. Then, it can be shown by using the same argument as in the case of constant returns to scale that the private gain from information acquisition is small, while the social gain is substantial. (Because of the complexity of the equilibrium values of Θ and others, we have to resort to numerical analysis in the case that $c_1 > 0$.) However, if c_1 is large, then the private gain becomes large.

Finally, let us consider the assumption of predetermined real wages. This assumption can be replaced with the assumption of predetermined nominal wages without changing qualitative results of this paper. A similar result is also obtained in the framework of short-run immobility of labor and efficient wage bargains (see Nishimura (1988)). However, if the wage is determined simultaneously with prices, then the argument in this paper may not hold true. This is because the wage will convey information about the monetary disturbances, which firms take into account in their price determination.

(1) THE CASE OF NO MONETARY INFORMATION.

Let P_i^{NM} be the solution of the right-hand side of (18). From (14) and (16) we obtain

$$(A1)\quad (P_i^{NM})^{1+c_1k} = \frac{(1+c_1)k}{k-1}\cdot GH_1^{c_1}A_i^{c_1}\cdot\frac{E[(\bar{P}^*(M,\Theta,\rho,\rho))^{(1+c_1)(k-1)}|A_i]}{E[(\bar{P}^*(M,\Theta,\rho,\rho))^{(k-2)}|A_i]}$$

$$=\frac{(1+c_1)k}{k-1}GH_1^{c_1}A_i^{c_1}\Theta^{1+c_1(k-1)}\cdot\exp[-\{1+c_1(k-1)\}z(\rho)\sigma_u^2]\cdot\frac{E[M^{(1+c_1)(k-1)\rho}|A_i]}{E[M^{(k-2)\rho}|A_i]}$$

Note that under the assumption made in the text, the distribution of ($\log M$, $\log A_i$) are multivariate normal distribution with mean (0, 0) and variance-covariance matrix Σ, such that

$$\Sigma = \begin{bmatrix} \sigma_m^2 & \sigma_m^2 \\ \sigma_m^2 & \sigma_m^2 + \sigma_u^2 \end{bmatrix}.$$

Consequently, the distribution of $\log M$ conditional on $\log A_i$, $\log M|\log A_i$, is a normal distribution with $E[\log M|\log A_i] = \theta\log A_i$ and $V[\log M|\log A_i] = \theta\sigma_u^2$, where $\theta = \sigma_m^2/(\sigma_m^2 + \sigma_u^2)$. Therefore, we obtain

$$\frac{E[M^{(1+c_1)(k-1)\rho}|A_i]}{E[M^{(k-2)\rho}|A_i]} = A_i^{\{1+c_1(k-1)\}\rho\theta}\exp\left[\omega\rho^2\theta\sigma_u^2\right]$$

where $\omega = \frac{1}{2}\{(1+c_1)^2(k-1)^2 - (k-2)^2\}$.

From (18), Θ and ρ must satisfy

(A2) $\Theta A_i^{\rho} = P_i^{NM}$.

Consequently, we obtain

$$\left[\Theta A_i^{\rho}\right]^{1+c_1k} = \frac{(1+c_1)k}{k-1} GH_1^{c_1} \Theta^{1+c_1(k-1)} A_i^{c_1+\{1+c_1(k-1)\}\rho\theta}$$

$$\cdot \exp\left[\omega\rho^2\theta\sigma_u^2 - z(\rho)\{1+c_1(k-1)\}\sigma_u^2\right].$$

Collecting terms in the above expression, we obtain the equilibrium value of Θ and ρ. We have because of (11)

$$\Theta = H_1 \exp\left[\frac{1}{c_1}\omega\rho^2\theta\sigma_u^2) - \frac{1+c_1(k-1)}{c_1}\{z(\rho) - z(\frac{c_1}{1+c_1k})\}\sigma_u^2\right],$$

and

$$\rho = \frac{c_1}{1 + c_1k - \{1 + c_1(k - 1)\}\theta}.$$

(2) THE CASE THAT MONETARY INFORMATION IS FREELY AVAILABLE.

Let P_i^M be the solution of the maximization of the right-hand side of (19). From (14) and (17) we obtain

(A3) $$(P_i^M)^{1+c_1k} = G\frac{(1+c_1)k}{k-1}\cdot H_1^{c_1} A_i^{c_1} (\bar{P}^*(M, \Phi, \delta, \lambda))^{1+c_1(k-1)}.$$

From (19), Φ, δ, and λ must satisfy

(A4) $\Phi M^{\delta} U_i^{\lambda} = P_i^{M}$.

Then we have

$$\Phi = H_1;\ \delta = 1;\ \text{and}\ \lambda = \frac{c_1}{1+c_1 k}.$$

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1. See, for example, Blanchard and Fischer (1989: Chapter 7) for a compact survey of the literature.

2. Alternatively, the labor union controls the labor market, but for some reason the union has to determine its real wage before the realization of monetary and preference disturbances.

3. There is a sizable literature about real wage rigidity during a business cycle in the United States. In a recent example, Blanchard and Fischer (1989: Chapter 1) report very little correlation between economywide real wages and output.

4. Because the case of no monetary information is the special case of monetary information with an additional constraint $\delta = \lambda$ $(= \rho)$, we first derive the price index in the case of monetary information. The price index in the case of no monetary information is obtained in a similar way.

Let f(U) be the density function of the log-normal distribution from which U_s (s = 1, ..., n) is drawn. Because n is large, the number of firms having U is approximately nf(U). Since $\phi(M, U_s) = \Phi M^{\delta} U_s^{\lambda}$, the log of the price index $\bar{P}(\{\phi(M, U_s)\}_{s=1,..,n})$ is

$$\log[\bar{P}(\{\phi((M, U_s)\}_{s=1,...,n})] = \frac{1}{1-k}\log\{\Sigma_{s=1}^{n} U_s\{\Phi M^{\delta} U_s^{\lambda}\}^{1-k} \cdot \frac{1}{n}\}$$

$$\approx \log\Phi + \delta\log M + \frac{1}{1-k}\log(\int_0^{\infty} U^{1+(1-k)\lambda} f(U)dU)$$

$$= \log\Phi + \delta\log M - z(\lambda)\sigma_u^2.$$

Here the property of the log-normal distribution is utilized.

5. Because all firms are symmetric, the unconditional payoff is the same for all firms.