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Monopolistic Competition, Imperfect Information, and Macroeconomics*

by

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* This paper is a substantially revised version of "Monopolistic Competition, Differential Information, and Macroeconomics I," June 1987.

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ABSTRACT

Price-making (quantity-taking) and quantity-making (price-taking) are commonly observed modes of behavior in monopolistically competitive markets. This study shows that macroeconomic consequences are very different between the two under imperfect and incomplete information. The price-making economy has high, sticky prices and fluctuating quantities, while the quantity-making economy has low, flexible prices and relatively stable quantities. Increased competition reduces price flexibility in the former, but increases in the latter. A simple characterization of welfare is presented. There are cases in the price-making economy in which increased price flexibility is accompanied by a reduction in welfare.

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1. INTRODUCTION

This paper investigates the effect of monopolistic competition on the behavior of prices and quantities under imperfect and incomplete information. Thus this paper is a preliminary attempt to integrate two strands of research in macroeconomics, namely, imperfect/incomplete information models (such as Lucas's (1972)), and monopolistic competition models (such as those of Hart (1979) and Blanchard and Kiyotaki (1987)). The approach taken here is close to that in Phelps et al. (1970), on which the two recent approaches draw heavily, in the sense that imperfect information and monopolistic competition are simultaneously analyzed. This paper is also a macroeconomic extension of industry analysis of Nishimura (1986).

Following the recent studies of monopolistic competition, I analyze an economy with differentiated products. Thus the economy is imperfectly segmented by many submarkets. As a source of informational separation of these submarkets, I consider (1) sluggish information diffusion and (2) a non-negligible production period.

In an economy with a large number of differentiated products, it is rather unrealistic to assume that all consumers are always aware of every change happened in the market. Consumers' information gathering and search activities are costly and time-consuming. Thus the transmission of information about firms usually takes time. Under such sluggish information diffusion, consumers have to cope with imperfect information as emphasized in the literature of economics of information.[1]

In such a market, however, firms may attract consumers by pledging prices and stable supply well in advance (through newspaper ads, for example), because such a strategy saves consumers' costs of information processing and search (see Okun (1981)).[2] Moreover, to make such a pledge is likely to be an equilibrium strategy, so long as (1) substitution between the products is relatively easy, (2) consumers' costs of information processing and search are sufficiently large, and (3) uncertainty about the market conditions is not large (see Nishimura (1988a)).[3] I call the economy in which the pledge is an equilibrium strategy the price-making economy. As Okun emphasizes, the price-making (quantity-taking) behavior is widely observed in various markets and industries. However, the price-making behavior means that the firm bears all risks stemmed from imperfect information. The imperfect/incomplete information firms face in the price-making economy is the first kind of imperfect/incomplete information analyzed in this paper.

Another possible source of imperfect/incomplete information is the existence of a production period.[4] If production takes time, the firm has to determine its production level before having perfect knowledge about the market. Once production is completed, the best decision of the firm is to sell all products at the market price. I call this case the quantity-making economy. This case assumes that information diffusion is sufficiently smooth that prices are determined at the level where the market clears. Thus quantity-making (price-taking) behavior is often found in organized markets of intermediate goods, in which auctioneer-like agents are present or trial-and-error pricing (Okun (1981)) is possible.

The purpose of this paper is to show that the two economies are very different in the way monetary disturbances affect the real sector. The price-making economy has high, sticky prices and fluctuating quantities. Contrary to the commonly-held view, increased competition among firms (or more precisely, among their products) reduces price flexibility and thus increases the volatility of output. Even if labor supply is inelastic, monetary disturbances still have a significant effect on the real sector, although the inelastic supply implies insulation of the real sector both in the perfect-competition imperfect-information model of Lucas and the menu-cost monopolistic-competition model of Blanchard and Kiyotaki. Imperfect and incomplete information raises the price level substantially in the long-run.

On the contrary, although the quantity-making economy also has fluctuating quantities, their magnitude is rather small compared with that in the price-making economy because the quantity-making economy has more flexible prices. Moreover, increased competition increases price flexibility, and inelastic labor supply implies the insulation. Although imperfect and incomplete information increases the long-run level of prices, its magnitude is small compared with that in the price-making economy. Thus the qualitative characteristics of the quantity-making equilibrium are closer to those of the perfect-competition imperfect-information models and the menu-cost monopolistic-competition models.

The plan of this paper is as follows. In Section 2 the model is presented and the basic relations are explained (their derivation is relegated to APPENDIX). In Section 3 the price-making equilibrium is analyzed, while in Section 4 the quantity-making equilibrium is investigated. A simple characterization of welfare is presented in Section 5. It is shown there that there are cases in the price-making economy in which increased price flexibility is accompanied by not an increase but a decrease in welfare.

2. A SIMPLE MACROECONOMIC MODEL WITH PRODUCT DIFFERENTIATION AND UNCERTAINTY

In developing a macroeconomic model of monopolistic competition under uncertainty, I make six basic choices. First, I assume the representative consumer-worker selling labor to each firm and receiving a share of each firm's profits. This aggregation of households makes analysis simple and enables us to analyze explicitly social welfare. Second, a bilateral monopoly and efficient bargains are assumed in the labor market. Workers are unionized firm by firm, and the firm maximizes the real joint benefit of the union and itself. This assumption is made in order to minimize the effect of labor market imperfection in the following argument.[5] Third, in order to link real variables with nominal ones in the simplest way, I have real balances in the utility function as in the recent literature of monopolistic competition (Weitzman (1985) and Blanchard and Kiyotaki (1987)).

Fourth, also following Weitzman and Blanchard and Kiyotaki, the utility function is specified in such a way as to lead to log-linear demand relations. Thus I adopt the constant elasticity of substitution specifications in utility from consumption. Fifth, departing the literature, I assume a continuum of differentiated products, each of which is produced by one firm. Although the CES specification yields log-linear demand functions, the associated price level is non-linear, which poses a difficult problem on expectation formation under uncertainty. The continuity assumption is made to circumvent the problem. Sixth, as the sources of uncertainty, I assume disturbances in money production and those in the representative consumer-worker's preference. The confusion between the macro disturbances and the micro ones is the source of monetary non-neutrality as in the perfect-competition imperfect-information models.

The Model

Consider an economy with a continuum of firms, each producing a specific product that is a imperfect substitute for other products. As a result, firms have some monopoly power with price-taking consumers in the product market, though they cannot influence aggregate variables. Consumer-workers in the economy are identical, selling labor to each firm and receiving a share of each firm's profits as dividends.

The government plays a minimal role in this economy. It produces nominal money, and transfers it to the consumer-workers at the beginning of each period. However, there is a disturbance in this production process, which is a source of the macroeconomic disturbance. Let M be the nominal money supply at the beginning of the period. I assume

$$(1) \qquad m = \log M \sim N(0, \sigma_m^2).$$

Thus M is log-normally distributed. The density of m is g(m). (For notational simplicity, I use the same term for a random variable and its particular realization in the following discussion. The distinction must be clear in the context.) The assumption of log-normal distribution greatly facilitates the expectation formation of economic agents.

In the following analysis, a lower case variable denotes the logarithm of the upper case one. For example, $x = \log X$.

The Representative Consumer-Worker

The representative consumer derives utility from leisure, consumption and real balances. The utility function is

$$(2) \qquad \Psi = (\bar{Y})^{\zeta} (\tilde{M}/\bar{P})^{1-\zeta} \{\zeta^{\zeta}(1-\zeta)^{(1-\zeta)}\}^{-1} - D,$$

where $\bar{Y} = [\int_{u=-\infty}^{u=+\infty} \int_{i=0}^{i=f(u)} \{e^u\}^{1/k} Q_{iu}^{(k-1)/k} \, di \, du]^{k/(k-1)}$,

$$\bar{P} = [\int_{u=-\infty}^{u=+\infty} \int_{i=0}^{i=f(u)} \{e^u\} P_{iu}^{1-k} \, di \, du]^{1/(1-k)},$$

and $D = [\int_{u=-\infty}^{u=+\infty} \int_{i=0}^{i=f(u)} L_{iu}^{\mu} \, di \, du]$.

The first term $\bar{Y}$ in utility is a consumption index, representing the effect of consumption of products on utility. The term e^u in the definition of $\bar{Y}$ is the preference disturbance. I assume

$$u \sim N(0, \sigma_u^2).$$

Thus the preference disturbance e^u is log-normally distributed. The microeconomic preference disturbance e^u is independent of the macroeconomic nominal disturbance M. The disturbance e^u groups the products into continuous "types" on the real line. The density of the products of type u is f(u), where f(u) is the density function of u. Products of the same type enter utility symmetrically. Q_{iu} is the consumption of the i-th product of type u. Thus $\bar{Y}$ is a CES function of the Q_{iu}'s. The parameter k is the elasticity of substitution between products in utility. I assume that k is greater than two.[6]

The second term gives the effect of real money balances on utility. ζ is a parameter between zero and unity. Nominal money balances are deflated by the nominal price index $\bar{P}$ associated with $\bar{Y}$. This index reflects the effect of preference disturbance. I hereafter refer $\bar{P}$ as the price level. The third term, $\{\zeta^{\zeta}(1 - \zeta)^{(1-\zeta)}\}^{-1}$, is a convenient normalization making the utility of income (or more precisely, real wealth) be equal to unity.

The final term in utility is the total disutility from work. L_{iu} denotes the amount of labor supplied to the firm producing the i-th product of type u. The term $\mu - 1$ is the elasticity of marginal disutility of labor; μ is assumed to be greater than unity.

I assume that consumers can make consumption decisions after observing their income and all the prices. Then there is no uncertainty about the consumer's consumption decision. Note that under the assumption of bilateral monopoly in the labor market, labor supply is not determined by the consumer-worker. Thus the consumption bundle is the only choice variable for the representative consumer-worker.

The representative consumer-worker maximizes utility Ψ with respect to Q_{iu} subject to a budget constraint. The budget constraint is given by

$$\int_{u=-\infty}^{u=+\infty} \int_{i=0}^{i=f(u)} P_{iu} Q_{iu} \, di \, du + \tilde{M} = B,$$

where $$B = \int_{u=-\infty}^{u=+\infty} \int_{i=0}^{i=f(u)} \{\Lambda_{iu} + \Pi_{iu}\} \, di \, du + M,$$

in which M denotes the initial endowment of money, and Λ_{iu} and Π_{iu} are wage payments and dividends from the firm producing the i-th product of type u.

Solving this consumption problem (see APPENDIX), we get the following demand for the i-th product of type u:

$$(3\ ) \qquad Q_{iu} = (P_{iu}/\bar{P})^{-k} \cdot \{(\zeta B)/\bar{P}\} \cdot e^{u}.$$

which implies

$$(4\ ) \qquad \int_{u=-\infty}^{u=+\infty} \int_{i=0}^{i=f(u)} P_{iu} Q_{iu} \, di \, du = \bar{P}\bar{Y} = \zeta B.$$

The demand for real money balances is

(5) $$\tilde{M}/\bar{P} = (1 - \zeta)(B/\bar{P}).$$

Finally, using the above results, we can rewrite the utility function as

(6) $$\Psi = \frac{B}{\bar{P}} - \int_{u=-\infty}^{u=+\infty} \int_{i=0}^{i=f(u)} L_{iu}^{\mu} \, di \, du.$$

The Firm

The firm producing the i-th product of type u does not retain its profits, so that the firm's budget is

(7) $$P_{iu}Q_{iu} = \Lambda_{iu} + \Pi_{iu}.$$

Under the bilateral monopoly and efficient bargains, the firm's objective function is the joint real benefits of the firm and its workers, which is equal to the representative consumer-worker's utility (6). Consequently, the firm's objective is to maximize $(P_{iu}Q_{iu}/\bar{P}) - L_{iu}^{\mu}$. The constraint given to the firm is the demand function (3) and the production function having the following form:

(8) $$Q_{iu} = L_{iu}^{\phi},$$

where $\phi \geq 1$, representing non-decreasing returns to scale. The firm knows the functional forms of (3) and (8) and the parameters k, ζ, μ, and ϕ.

Let us consider information available to the firm. First, the firm cannot observe ζB and e^u in the demand function independently. Instead the firm is assumed to observe the composite of the two such that

$$(9) \qquad e^{\alpha} = \zeta B \cdot e^{u}.$$

I hereafter call α as the individual demand disturbance. Then the demand for the i-th product of type u is

$$(10) \qquad Q_{iu} = (P_{iu}/\bar{P})^{-k} \cdot (\bar{P})^{-1} \cdot e^{\alpha}.$$

Under this assumption, the firm knows all relevant information about the demand except the price level. Second, the firm cannot observe the price level when it determines its action. The firm forms expectations about $\bar{P}$ relying on information Ω available to the firm.

The firm is endowed with rational expectations. The firm assumes that $\bar{p} = \log\bar{P}$ is normally distributed with mean $e(\bar{p}|\Omega)$ and variance $V(\bar{p}|\Omega)$, where $e(\bar{p}|\Omega)$ is the linear least squares regression of $\bar{p}$ on Ω including α, and $V(\bar{p}|\Omega)$ is its error variance. In our model, it turns out that (i) $e(\bar{p}|\Omega)$ is equal to the mathematical expectation of $\bar{p}$ conditional on α, and (ii) $V(\bar{p}|\Omega)$ is independent of information α.

(1) Price-Making Quantity-Taking Behavior

Let us first assume that the firm announces its price and satisfies all the demand it creates.[7] In this case the firm maximizes the following expected real joint benefits of itself and its union:

$$\max_{P_{iu}} E_{\bar{P}} \left[(P_{iu}/\bar{P})Q_{iu} - L_{iu}{}^{\mu} \right],$$

subject to (10) and (8). Here $E_{\bar{P}}$ is the expectation operator with respect to the firm's subjective distribution of $\bar{P}$.

Under our expectational assumption, the first order condition of optimality can be transformed into the following optimal pricing formula in logarithm (see APPENDIX):

(11) $$p_{iu} = (1 + c_1 k)^{-1}[a + c_1\alpha + \{1 + c_1(k - 1)\}e(\bar{p}|\Omega)],$$

where

(12) $$c_1 = (\mu/\phi) - 1,$$

$$a = \log(1 + c_1) + \log\{k/(k - 1)\} + \omega V(\bar{p}|\Omega),$$

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

in which the coefficient ω of $V(\bar{p}|\Omega)$ is positive under our assumptions.

(2) Quantity-Making Price-Taking Behavior

In this case the firm sets the production level, and attempts to sell all of its products at the market price. The firm is still assumed to be ignorant about the price level (and the average output level) in the market, when it determines its production level. The firm's problem is now the following:

$$\underset{Q_{iu}}{\mathrm{Max}}\ E_{\bar{P}}\ [(P_{iu}/\bar{P})Q_{iu} - L_{iu}{}^{\mu}],$$

subject to (8) and

$$(13) \qquad P_{iu}/\bar{P} = \{Q_{iu}\cdot(\bar{P})\}^{-1/k}\cdot(e^{\alpha})^{1/k},$$

which is a transformation of (10).

The first order condition of optimality yields the following optimal production formula in logarithm (see APPENDIX):

$$(14) \qquad q_{iu} = (1 + c_1 k)^{-1}\{- kb - e(\bar{p}|\Omega) + \alpha\},$$

where

$$b = \log(1 + c_1) + \log\{k/(k - 1)\} - \omega' V(\bar{p}|\Omega),$$

$$\omega' = (1/2)k^{-2}.$$

The Symmetric Equilibrium

Because there are only money and products in this economy, the economy is in equilibrium if and only if the money market is equilibrium. The equilibrium condition in the money market is

$$(15) \qquad \tilde{M} = M.$$

Under this equilibrium condition, we have from individual demand functions (3) and (5)

(16) $$\bar{Y} = (\frac{\zeta}{1-\zeta})\frac{M}{\bar{P}}.$$

Thus in equilibrium the aggregate demand is determined by real balances. Consequently, because $\bar{P}\bar{Y} = \zeta B$, we obtain in equilibrium

(17) $$\alpha = h_1 + m + u, \text{ where } h_1 = \log\{\zeta/(1-\zeta)\}.$$

This implies that the individual demand disturbance α consists of the macroeconomic nominal disturbance m and the microeconomic real disturbance u.

In the following analysis, we are concerned with symmetric equilibrium in which $p_{iu} = p_{ju} = p_u$ and $q_{iu} = q_{ju} = q_u$ for all $i \neq j$ and all u. In the symmetric equilibrium, the expression of the equilibrium price level is greatly simplified.

As a frame of reference, let us first consider the case of complete information. Let the superscript * denote the complete-information equilibrium. In the case of complete information, $e(\bar{p}^*|\Omega) = \bar{p}^*$ and $V(\bar{p}^*|\Omega) = 0$. Then it is straightforward to show (see APPENDIX) that in equilibrium

$$p_u^* - \bar{p}_u^* = \rho^* u, \text{ where } \bar{p}_u^* = \int_{u=-\infty}^{u=+\infty} p_u^* f(u)du \text{ and } \rho^* = \frac{c_1}{1 + c_1 k},$$

and the log of the price level is simply

$$\bar{p}^* = \bar{p}_u^* - z(\rho^*) \text{ where } z(\rho^*) = \frac{\{1-(k-1)\rho^*\}^2}{2(k-1)} \sigma_u^2.$$

In the incomplete-information cases, it turns out that similar relations hold true. The equilibrium relative prices and the log of the price level can be shown to satisfy

(18) $$p_u - \bar{p}_u = \rho u, \text{ where } \bar{p}_u = \int_{u=-\infty}^{u=+\infty} p_u f(u)du, \text{ and}$$

(19) $$\bar{p} = \bar{p}_u - z(\rho),$$

in which the term ρ is endogenously determined and dependent on the behavior of firms. The equation (19) shows that an increase in ρ, which implies more variable relative prices, increases the price level if $\rho < 1/(k - 1)$. This inequality in general holds true (for example, ρ^* satisfies this), except for cases in the price-making economy in which k is very large.

3. PRICE-MAKING EQUILIBRIUM: HIGH, RIGID PRICES AND FLUCTUATING QUANTITIES

Let us denote the price-making equilibrium with no superscript. In this case the equilibrium is characterized by (17), (19), and

$$(20)\qquad p_u = \frac{1}{1 + c_1 k} a + \frac{c_1}{1 + c_1 k} \alpha + (1 - \frac{c_1}{1 + c_1 k}) e(\bar{p}|\Omega),$$

which is from (11). This price equation shows that the individual price is the weighted average of the individual demand disturbance and the expected average price.

Using the undetermined coefficient method (see APPENDIX), we obtain

$$(21)\qquad e(\bar{p}|\Omega) = \frac{1}{c_1} a + h_1 - \frac{1+c_1 k}{c_1} z(\rho) + \frac{c_1}{1+c_1 k-\{1+c_1(k-1)\}\theta} \theta(\alpha - h_1),$$

where $\theta = \sigma_m^2/(\sigma_m^2 + \sigma_u^2)$, and

$$(22)\qquad \rho = \frac{c_1}{1 + c_1 k - \{1 + c_1(k - 1)\}\theta}.$$ [8]

These expectations imply

$$(23)\qquad \bar{p} = \frac{1}{c_1} a + h_1 - \frac{1+c_1 k}{c_1} z(\rho) + \frac{c_1}{1+c_1 k-\{1+c_1(k-1)\}\theta} m.$$

From the above average price formula we obtain

$$(24)\qquad V(\bar{p}|\Omega) = \{\frac{c_1}{1+c_1 k-\{1+c_1(k-1)\}\theta}\}^2 (1 - \theta)\sigma_m^2 = (1 - \theta)V(\bar{p}).$$

Here $V(\bar{p})$ is the true long-run variance of $\bar{p}$ such that

$$V(\bar{p}) = \int_{m=-\infty}^{m=+\infty} (\bar{p} - \bar{\bar{p}})^2 g(m)dm, \text{ where } \bar{\bar{p}} = \int_{m=-\infty}^{m=+\infty} \bar{p}\, g(m)dm.$$

The equations (22) through (24) completely characterize the equilibrium.

<u>Sensitivity Analysis</u>

The equilibrium is depicted in Figures 1 and 2 in terms of the demand sensitivity of the average price and the average expectations. Let us define

(1) the average expectations: $\bar{e}(\bar{p}|\Omega) \equiv \int_{u=-\infty}^{u=+\infty} e(\bar{p}|\alpha = h_1 + m + u)f(u)du$;

(2) the sensitivity of the price level: $\eta(\bar{p}) \equiv \{\bar{p} - \bar{\bar{p}}\}/m$,

(3) the sensitivity of the average expectations: $\eta(\bar{e}(\bar{p}|\Omega)) = \{\bar{e}(\bar{p}|\Omega) - \bar{\bar{p}}\}/m$.

Then the optimal pricing formula (20) is transformed into

$$\text{(25)} \qquad \eta(\bar{p}) = \frac{c_1}{1+c_1 k} + \left(1 - \frac{c_1}{1+c_1 k}\right) \eta(\bar{e}(\bar{p}|\Omega)).$$

It can easily be shown that (25) holds for both of the complete-information case and the incomplete-information one (see APPENDIX). However, the relationship between $\eta(\bar{e}(\bar{p}|\Omega))$ and $\eta(\bar{p})$ is different between the two. In the complete information case, we have by definition

$$\text{(26)} \qquad \eta(\bar{e}(\bar{p}|\Omega)) = \eta(\bar{p}),$$

while in the incomplete information case, we get

$$\eta(\bar{e}(\bar{p}|\Omega)) = \theta\eta(\bar{p}). \tag{27}$$

Because of the possibility of local-global confusion, the average expectations about the price level is not so sensitive to the demand disturbance as the price level itself. This stickiness of the average expectations makes the incomplete-information price level less sensitive than the complete-information one, and produces short-run non-neutrality of money as in the perfect-competition imperfect-information models. Figure 1 illustrates the point. In this figure the sensitivity of the price level is on the vertical axis, while that of the average expectations on the horizontal axis. The line AB represents (25), which shows the sensitivity of the price level given the level of the average expectations. The line OC is the forty-five degree line, representing the dependence of the average expectations on the actual price level under complete information (26). The line OD is its incomplete-information counterpart (27). Because θ is less than unity, OD is always steeper than OC. The complete-information equilibrium is the intersection E^* of AB and OC, while the incomplete-information equilibrium is E of AB and OD. From this figure it is evident that the incomplete-information sensitivity is less than unity.

Using this figure, we can analyze the effects of competition and inelastic labor supply. Let us first consider the effect of competition. The appropriate measure of competition in this monopolistically competitive economy is the degree of substitution, k, among firms' products. Suppose that k is increased. In Figure 1, an increase in k implies the curve AB (the equation (25)) rotates counterclockwise around E^*, so that the new incomplete-information equilibrium E' is below the old E. Thus under incomplete information increased competition <u>reduces</u> the sensitivity of prices to the demand disturbance m. Under monopolistic competition, increased competition implies that the firm has to shift weights from its own conditions to the expected average price in determining its price (see (20)). Because the expected average price is less sensitive to m than the individual demand conditions, the shift implies the stickier prices. In the extreme case where k goes to infinity, $\partial\bar{p}/\partial m$ approaches zero, implying completely rigid prices.

Second, the effect of inelastic labor supply is illustrated in Figure 2. In this model, inelastic labor supply is represented by a large c_1 (= $(\mu/\phi) - 1$). In Figure 2, an increase in c_1 makes the AB curve rotate clockwise around E^*. Thus the new equilibrium E' is above the old E, implying that prices become more flexible. However, the flexibility is less than complete (that is, less than unity) even if c_1 is large. If c_1 goes to infinity, $\partial\bar{p}/\partial m$ approaches $\{(1 - \theta)k\}^{-1}$, which is less than unity because $1 > \theta > 0$ and $k > 2$. Thus in this economy, even if labor supply is inelastic, the monetary disturbance produces a large fluctuation in real variables.

Level Analysis

In the monopolistically competitive economy, incomplete information also influences the long-run position of equilibrium. From the above equilibrium characterization (and the result obtained in APPENDIX), we obtain the long-run price level under incomplete information, $\bar{\bar{p}}$, and that under complete information, $\bar{\bar{p}}^*$, such that

(28) $$\bar{\bar{p}} = \frac{1}{c_1} a + h_1 - \frac{1+c_1 k}{c_1} z(\rho) \text{ and } \bar{\bar{p}}^* = \frac{1}{c_1} a^* + h_1 - \frac{1+c_1 k}{c_1} z(\rho^*),$$

where $a^* = \log(1 + c_1) + \log\{k/(k - 1)\}$. Consequently we obtain

$$(29) \qquad \bar{\bar{p}} - \bar{\bar{p}}^* = \frac{\omega}{c_1} V(\bar{p}|\Omega) + \frac{1+c_1 k}{c_1}\{z(\rho^*) - z(\rho)\}.$$

The two terms in the right-hand side of (29) represent the effect of imperfect and incomplete information about the long-run position of the price level.

The first term is the effect of uncertainty about $\bar{p}$ on the long-run position of $\bar{p}$. Uncertainty about the price level unambiguously increases the price level under our assumption. Note that price-level uncertainty has two effects. First, it increases the uncertainty about the sales through the demand function (11). Because (i) the marginal cost of the firm-union is convex in the sales and (ii) the sales are convex in $\bar{p}$, increased uncertainty about $\bar{p}$ decreases the marginal benefit of production. Second, the price-level uncertainty induces uncertainty about the firm's own relative price. Because the relative price is a convex function of $\bar{p}$, the price-level uncertainty increases the the marginal revenue. However, under the assumption that $k > 2$, the first effect dominates the second. Thus the firm-union increases its price on the average in order to reduce the demand.

Imperfect and incomplete information influences the price level by increasing the variability of the relative prices (that is, by increasing ρ). The second term in (29) represents this effect. The sign of the second term is in general ambiguous, though it is likely to be positive in realistic cases.[9] However, the second term is always dominated by the first term, so that we obtain

$$(30) \qquad \bar{\bar{p}} - \bar{\bar{p}}^* = \frac{\{1+c_1(k-1)\}^2[(2+c_1+c_1k)(1-\theta)+c_1k(1+c_1)]}{2(1+c_1k)[1+c_1k-\{1+c_1(k-1)\}\theta]^2}(1-\theta)\sigma_m^{\,2} > 0.$$

Thus imperfect and incomplete information unambiguously increases the long-run price level.

Using the above equation, we can analyze the effects on the long-run price level of competition and inelastic labor supply. We obtain

$$\lim_{k\to\infty} \bar{\bar{p}} - \bar{\bar{p}}^* = \frac{2+c_1-\theta}{1-\theta}\sigma_m^2 \quad \text{and} \quad \lim_{c_1\to\infty} \bar{\bar{p}} - \bar{\bar{p}}^* = \infty.$$

Because θ is likely to be small, $\bar{\bar{p}}$ is much larger than $\bar{\bar{p}}^*$ when k becomes large. Also, inelastic labor supply leads to a high long-run price level.

In the price-making quantity-taking economy, the firm always faces the possibility of being obliged to supply more than it wants to. This is the cost of price-making quantity-taking. The cost becomes larger when (1) the economy is more competitive (the elasticity of substitution is larger) and/or (2) the marginal cost increases more rapidly. Because firms are _ex ante_ symmetric (that is, they are homogeneous if $u = 0$), the firm knows other firms' cost of price-making quantity-taking. Consequently the firm puts a high price tag on its products in order to compensate a high cost of price-making in such cases, anticipating other firms also charge high prices. Their anticipations are fulfilled in equilibrium. Thus even though the cost of price-making is high for large k and c_1, the firm still obtains positive expected profits through high long-run prices.

4. QUANTITY-MAKING EQUILIBRIUM: LOW, FLEXIBLE PRICES AND RELATIVELY STABLE QUANTITIES

The quantity-making equilibrium is characterized by (17), (19),

(31) $$p_u = -\frac{1}{k} q_u + (1 - \frac{1}{k})\bar{p} + \frac{1}{k}\alpha, \text{ and}$$

(32) $$q_u = \frac{1}{1+c_1k} \{-kb - e(\bar{p}|\Omega) + \alpha\}.$$

Let ' denote the quantity-making equilibrium. Using the undetermined coefficient method (see APPENDIX), we obtain

(33) $$e(\bar{p}'|\Omega) = \frac{b}{c_1} + h_1 - \frac{1+c_1k}{c_1} z(\rho') + \frac{c_1k}{1+c_1k-\theta} \theta(\alpha - h_1), \text{ and}$$

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

Consequently we obtain

(35) $$\bar{p}' = \frac{b}{c_1} + h_1 - \frac{1+c_1k}{c_1} z(\rho') + \frac{c_1k}{1+c_1k-\theta} m, \text{ and}$$

(36) $$V(\bar{p}'|\Omega) = (\frac{c_1k}{1 + c_1k - \theta})^2(1 - \theta)\sigma_m^{\ 2} = (1 - \theta)V(\bar{p}').$$

Sensitivity Analysis

Using the same figure as before, we can analyze the sensitivity of the quantity-making equilibrium to nominal demand disturbances. For the quantity-making equilibrium, we obtain

(37) $$\eta(\bar{p}') = \frac{c_1k}{1 + c_1k} + (1 - \frac{c_1k}{1 + c_1k})\ \eta(\bar{e}(\bar{p}'|\Omega)).$$

In Figure 3, the curve GH represents (37). G is unambiguously above A, so that the quantity-making equilibrium is above the price-making one. Consequently, prices are more sensitive in the former. This is because the firm's actual price is more flexible in the quantity-making equilibrium. Although the firm's production level is dependent on the sticky price-level expectations, the firm's price also depends on the actual average price other than its production level. Moreover, the effect of the price-level expectations is dominated by that of the actual price level. From (32) and (31) we have

(38) $$p_u' = \frac{1}{(1+c_1k)}b + \frac{1}{k(1+c_1k)}e(\bar{p}'|\Omega) + (1 - \frac{1}{k})\bar{p}' + \frac{1}{k}(1 - \frac{1}{1+c_1k})\alpha.$$

The coefficient of $e(\bar{p}|\Omega)$ is much smaller than that of $\bar{p}$. Consequently the effect of sticky expectations is substantially weakened.

The effects of competition and inelastic labor supply on the sensitivity of prices are illustrated in Figure 4. An increase in k rotates GH clockwise, so that increased competition increases the sensitivity. In the extreme case that k goes to infinity, prices become perfectly sensitive to m ($\partial\bar{p}/\partial m$ approaches unity). Thus the effect of competition in the quantity-making equilibrium is just opposite to that in the price-making equilibrium. As in the price-making equilibrium, increased competition makes the firm's price more sensitive to the economy-wide condition than the firm-specific condition. However, unlike the price-making equilibrium, this implies the firm's price is more sensitive to the actual price level, not the expectations about it. The price-level expectations are the determinant of the firm-specific condition, namely, the firm's production level, which has a smaller weight in the price equation. Consequently increased competition increases the sensitivity.

On the contrary, the effect of inelastic supply is qualitatively the same as in the price-making equilibrium. An increase in c_1 rotates GH clockwise, and makes the price level more sensitive to m. Moreover, if c_1 goes to infinity, prices become perfectly sensitive to m ($\partial\bar{p}/\partial m$ approaches unity). In this respect, the effect of inelastic labor supply is stronger in the quantity-making equilibrium than in the price-making equilibrium.

Level Analysis

Next, we compare the long-run position of the quantity-making equilibrium with that of the complete-information equilibrium. The long-run level of the price level in the quantity-making equilibrium, $\bar{\bar{p}}'$, is from the above equilibrium characterization

$$(39) \qquad \bar{\bar{p}}' = \frac{b}{c_1} + h_1 - \frac{1+c_1 k}{c_1} z(\rho').$$

Consequently we obtain

$$(40) \qquad \bar{\bar{p}}' - \bar{\bar{p}}^* = -\frac{\omega'}{c_1} V(\bar{p}'|\Omega) + \frac{1+c_1 k}{c_1} \{z(\rho^*) - z(\rho')\}.$$

Unlike the price-making equilibrium, the effect of uncertainty about the price level (the first term) decreases the long-run price level. This is because there is no uncertainty about the sales in the quantity-making equilibrium. Consequently the price-level uncertainty affects the firm-union's joint benefit only through uncertainty about the own relative price. Because of the convexity of the relative price with respect to $\bar{p}$, the price-level uncertainty increases the marginal revenue, so that the firm reduces its price in order to induce more sales.

The price-reducing effect of the price-level uncertainty, however, is dominated by the effect of the relative price variability caused by imperfect/incomplete information (the second term). The effect of the relative-price variability increases the price level unambiguously in the quantity-making equilibrium, and it is larger than the price-reducing effect of the price-level uncertainty. Consequently we have

$$(41) \qquad \bar{\bar{p}}' - \bar{\bar{p}}^* = \frac{(2+c_1+c_1k)(1-\theta)+c_1k(1+c_1)}{2(1+c_1k)(1+c_1k-\theta)^2}(1-\theta)\sigma_m^{\ 2} > 0.$$

This equation shows that $\bar{\bar{p}}'$ approaches $\bar{\bar{p}}^*$ if k goes to infinity. Because the complete-information price level converges the perfect-competition perfect-information price level in this case, the incomplete-information price-level also approaches the perfect-competition perfect-information price level. This result is in sharp contrast with the price-making equilibrium, in which increased competition leads to sticky prices. Similarly, $\bar{\bar{p}}'$ converges $\bar{\bar{p}}^*$ if c_1 goes to infinity. Thus if k and/or c_1 are sufficiently large, imperfect/incomplete information does not matter in the quantity-making equilibrium.

5. WELFARE

Equilibrium Welfare

The appropriate criterion of the social welfare is the expected utility of the representative consumer-worker:

(42) $$W = E\Psi = \int_{m=-\infty}^{m=+\infty} \Psi g(m)dm.$$

In the price-making equilibrium, the distribution of P_u is determined for a particular realization of M. This equilibrium distribution of P_u determines $\bar{P}$ and $\bar{Y}$. Then the representative consumer-worker's utility is from (3) through (8)

$$\Psi = \frac{1}{\zeta}\bar{Y} - \int_{u=-\infty}^{u=+\infty} L_u^{\mu} f(u)du, \text{ where } L_u = [e^u(\frac{P_u}{\bar{P}})^{-k}\bar{Y}]^{1/\phi}.$$

Because in equilibrium (18) holds true, we obtain, using the characteristics of log-normal distribution,

(43) $$\Psi = \frac{1}{\zeta}\bar{Y} - (\bar{Y})^{1+c_1}\cdot\exp[\Gamma(\rho)], \text{ where}$$

(44) $$\Gamma(\rho) = (1/2)[(1+c_1)^2(1 - k\rho)^2 - \{k/(k - 1)\}(1+c_1)\{1 - (k - 1)\rho\}]\sigma_u^2.$$

Consequently we obtain

$$W = E\Psi = \frac{1}{\zeta}E\bar{Y} - E(\bar{Y})^{1+c_1}\cdot\exp[\Gamma(\rho)].$$

Note that in equilibrium we have

$$(45) \qquad \bar{y} = h_1 + m - \bar{p} = \bar{\bar{y}} + \varepsilon m,$$

where

$$(46) \quad \bar{\bar{y}} = -\frac{1}{c_1}\log\frac{k}{k-1} - \frac{1}{c_1}\log(1+c_1) + \frac{1+c_1 k}{c_1}z(\rho) - \frac{\omega}{c_1}V(\bar{p}|\Omega), \text{ and}$$

$$(47) \qquad \varepsilon = \frac{\{1 + c_1(k - 1)\}(1 - \theta)}{1 + c_1 k - \{1 + c_1(k - 1)\}\theta}.$$

Thus we obtain

$$(48) \quad W = W(\bar{Y}, V(\bar{y}), \Gamma(\rho)) = \frac{1}{\zeta}\bar{Y}\cdot\exp[\tfrac{1}{2}V(\bar{y})] - (\bar{Y})^{1+c_1}\cdot\exp[\tfrac{1}{2}(1+c_1)^2V(\bar{y})+\Gamma(\rho)].$$

where $\bar{Y} = \exp[\bar{\bar{y}}]$. Here the fact that $\bar{Y}$ is log-normally distributed in equilibrium is utilized.

A similar characterization is also possible for the quantity-making price-taking equilibrium. The equilibrium welfare is

$$(49) \quad W' = W(\bar{Y}', V(\bar{y}'), \Gamma(\rho')),$$

where $\bar{y}' = \bar{\bar{y}}' + \varepsilon' m$, in which

$$(50) \quad \bar{\bar{y}}' = -\frac{1}{c_1}\log\frac{k}{k-1} - \frac{1}{c_1}\log(1+c_1) + \frac{1+c_1 k}{c_1}z(\rho') + \frac{\omega'}{c_1}V(\bar{p}'|\Omega), \text{ and}$$

$$(51) \qquad \varepsilon' = \frac{1 - \theta}{1 + c_1 k - \theta}.$$

Social Planner's Problem

As a frame of reference, let us consider the "social planner," who controls all the firms in the economy. The behavior of consumers and the characteristics of the monetary disturbance are given to him. Thus the social planner knows the true values of m and u, and determines the distribution of P_u in order to maximize W. Let the superscript o denote the social planner's optimal choice. The social planner' policy is described as a triplet $(\bar{\bar{y}}^o, \varepsilon^o, \rho^o)$ such that

$$(52) \qquad p_u{}^o - \bar{p}_u{}^o = \rho^o u \text{ and } \bar{y}^o = \bar{\bar{y}}^o + \varepsilon^o m.$$

Note that if one of $\bar{p}$, $\bar{y}$, and $\bar{p}_u$ is determined, then the other two are determined. Thus the above triplet completely characterizes the social planner's policy.

The social planner's problem is then

$$\max_{\bar{\bar{y}}^o,\ \varepsilon^o,\ \rho^o} \quad W(\exp[\bar{\bar{y}}^o],\ (\varepsilon^o)^2\sigma_m{}^2,\ \Gamma(\rho^o)).$$

It is easy to show that the socially optimal triplet is such that

$$(53)\ (\bar{\bar{y}}^o, \varepsilon^o, \rho^o) = (\frac{1}{c_1}\log \varsigma^{-1} - \frac{1}{c_1}\log(1+c_1) + \frac{1+c_1k}{c_1}z(\rho^o),\ 0,\ \frac{c_1}{1 + c_1k}).$$

Let us compare the social optimum with the perfect-competition perfect-information equilibrium, which is denoted by the superscript c, and the monopolistic-competition perfect-information equilibrium, denoted by the superscript *. In the the perfect-competition perfect-information equilibrium, all firms behave as price-takers, and know the price level as well as the individual market price. It is easy to show that $\varepsilon^c = \varepsilon^* = 0$, $\rho^c = \rho^* = \rho^o$,

$$(54) \qquad \bar{\bar{y}}^c = \bar{\bar{y}}^o - \frac{1}{c_1}\log \zeta^{-1}, \text{ and } \bar{\bar{y}}^* = \bar{\bar{y}}^c - \frac{1}{c_1}\log\frac{k}{k-1}.$$

The first equation implies that perfect competition fails to achieve the optimum output. This is because real balances are in the representative consumer-worker's utility. Perfect competition guarantees only the production efficiency, and fails to maximize utility from the real balances. In fact, the competitive output $\bar{\bar{y}}^c$ maximizes

$$\bar{Y} - (\bar{Y})^{1+c_1}\cdot\exp[\Gamma(\rho^c)],$$

and fails to take into account the contribution of real balances to welfare, which is equal to the value of real balances itself under our assumption.[10] The difference between the perfect-competition output and the monopolistic-competition one reflects the monopoly power.

The Second-Order Approximation of Social Welfare around the Social Optimum.

Although the equilibrium welfare (48) ((49)) is non-linear and complicated, there exists a convenient second-order approximation of the equilibrium welfare around the social optimum (53). Let us take the second-order Taylor expansion of $W = W(\bar{Y}, \varepsilon^2\sigma_m{}^2, \Gamma(\rho))$((48)) with respect to $(\bar{Y}, \varepsilon, \Gamma(\rho))$ around the social optimum $W^o = W(\bar{\bar{Y}}^o, (\varepsilon^o)^2\sigma_m{}^2, \Gamma(\rho^o))$. It is straightforward to prove that the normalized welfare loss $(W - W^o)/W^o$ is approximately equal to the following expression.[11]

(55) $(W - W^o)/W^o$

$$\approx -\frac{1}{2}(1 + c_1)[\{\exp(\bar{\bar{y}} - \bar{\bar{y}}^o) - 1\}^2 + V(\bar{y}) + \frac{k(1+c_1k)}{c_1}(\rho - \rho^o)^2\sigma_u^{\,2})].$$

A similar result is also obtained for (49).

In (55), the first term represents the loss in welfare due to underproduction, which is discussed below. The second term is the welfare loss due to macroeconomic instability, while the third term is the welfare loss due to microeconomic instability. This is the loss due to excessive relative price variability, because it is equal to $V((p_u - \bar{p}_u) - (p_u^{\,o} - \bar{p}_u^{\,o}))$.

The welfare loss due to underproduction consists of three parts. For the price-taking equilibrium, we obtain from (46) and (53) the following output loss

$$(56)\quad \bar{\bar{y}}^o - \bar{\bar{y}} = \bar{\bar{y}}^o - \bar{\bar{y}}^* + \frac{1+c_1k}{c_1}\{z(\rho) - z(\rho^o)\} + \frac{\omega}{c_1}(1 - \theta)V(\bar{p}).$$

For the quantity-making equilibrium, we obtain

$$(57)\quad \bar{\bar{y}}^o - \bar{\bar{y}}' = \bar{\bar{y}}^o - \bar{\bar{y}}^* + \frac{1+c_1k}{c_1}\{z(\rho') - z(\rho^o)\} - \frac{\omega'}{c_1}(1 - \theta)V(\bar{p}').$$

The first term in the above two equations has already discussed. The second term is the output loss due to the excessive variability of the relative price. The third is the output loss in the price-making economy (gains in the quantity-making economy) due to the variability of the price level. It has been shown in Section 3 that the overall effect of the second and third is positive in both cases. Thus the incomplete information equilibria are characterized by underproduction.

Comparison between the price-making equilibrium welfare and the quantity-making one is somewhat more complicated. Although the welfare loss due to both macroeconomic and microeconomic instability is larger in the price-making equilibrium because $\varepsilon > \varepsilon'$ and $\rho > \rho'$, the sign of the difference in the welfare loss due to underproduction is in general ambiguous. However, numerical analysis indicates that the loss is much larger in the price-making equilibrium under realistic parameter values.

Competition, Price Flexibility and Welfare

Let us consider the effect of increased competition (an increase in k) on the normalized welfare loss $((W - W^o)/W^o)$. Because k enters in the normalized welfare loss in a complicated way, we have to resort to numerical analysis. Figure 5 presents a typical case of price-making equilibrium. In this example, the values of parameters are: $\zeta = 0.3$, $c_1 = 3$, $\sigma_u^2 = 0.02$, and $\sigma_m^2 = 0.01$. The value of k, varying from 2.1 to 14.5, is on the horizontal axis, and the corresponding normalized welfare loss $(W - W^o)/W^o$ is on the vertical axis. Under the assumed value of parameters, the coefficient of variation of $\bar{y}$ varies from 0.1 to 0.15. Thus this example is a reasonable one. It is evident from this figure that an increase in competition reduces normalized welfare loss. Numerical experiments show that competition reduces normalized welfare loss so long as the value of c_1 is not large.[12]

An interesting corollary of this example is that in the price-making equilibrium, the price flexibility is often accompanied by not an decrease but an increase in the welfare loss. As it has already shown in the previous section, an increase in k decreases the sensitivity of prices. In Figure 5, the locus of price sensitivity $\eta(\bar{p})$ is also drawn. It is evident from this figure that price flexibility is accompanied by an increase in the welfare loss.

The relation between price flexibility and welfare is quite different in the quantity-making equilibrium. Figure 6 presents the quantity-making equilibrium corresponding to Figure 5. This figure shows that competition reduces the welfare loss, as in Figure 5. However, because in the quantity-making equilibrium an increase in k implies an increase in price sensitivity, price flexibility is positively correlated with welfare-loss reduction.

This difference between the two equilibrium is stemmed from the role of uncertainty about the price level on the welfare loss. The price-level uncertainty reduces the long-run output substantially in the price-making equilibrium, while it increases the long-run output a little in the quantity-making equilibrium. An increased price flexibility means in many cases an increase in the price level uncertainty. Thus price flexibility is often accompanied by welfare reduction in the price-making equilibrium, whereas such an association is not present in the quantity-making equilibrium.

6. CONCLUDING REMARKS

The results of this paper show that the price-making economy exhibits price rigidity in a wide range of parameters. Although perfect-competition imperfect-information models and menu-cost monopolistic-competition models fail to generate large fluctuations in output in response to demand if real wage elasticity of labor supply is low, the combination of the imperfect information and monopolistic competition is capable of generating such fluctuations. Thus the results reported here show the possibility of constructing a model of output fluctuations without resorting additional assumptions such as permanent-transitory confusion, union preferences, and efficiency wages.

The crucial assumption is, of course, that of price-making quantity-taking. I have adopted the argument developed in Okun (1981), arguing that such a strategy is likely to be an equilibrium one in an economy with sluggish information diffusion and costly search. The argument seems plausible for the markets of services, such as hotels, to a certain extent.[13] It is also likely to hold for products which consumers buy frequently. However, it is not certain that the theory is also capable of explaining sticky prices of automobiles and large household appliances, because many consumers search actively in these markets. We may need some additional assumptions there such as asymmetric information about quality.

The quantity-making equilibrium is of interest because imperfect information due to purely technical constraints is not likely to change the working of the economy very much, so long as the economy is competitive. In such cases we can safely ignore imperfect information.

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APPENDIX

The Derivation of the Demand Functions

The representative consumer-worker maximizes his utility in two steps.

(i) The first step. Maximize the utility index of differentiated products.

$$\max_{Q_{iu}} \left[\int_{u=-\infty}^{u=+\infty}\int_{i=0}^{i=f(u)} \{e^{u}\}^{1/k} Q_{iu}{}^{(k-1)/k} di du\right]^{k/(k-1)}$$

$$\text{s.t.} \int_{u=-\infty}^{u=+\infty}\int_{i=0}^{i=f(u)} P_{iu} Q_{iu} di du = B^{*},$$

where B^{*} is the expenditure on the products. The first-order condition is then

$$\left[\int_{u=-\infty}^{u=+\infty}\int_{i=0}^{i=f(u)} \{e^{u}\}^{1/k} Q_{iu}{}^{(k-1)/k} di du\right]^{\{k/(k-1)\}-1} \{e^{u}\}^{1/k} Q_{iu}{}^{\{(k-1)/k\}-1} = \lambda P_{iu},$$

where λ is the Lagrangian multiplier of the constraint. Multiply Q_{iu} on both sides and integrate the resulting expression over u and i. Then we obtain

$$\left[\int_{u=-\infty}^{u=+\infty}\int_{i=0}^{i=f(u)} \{e^{u}\}^{1/k} Q_{iu}{}^{(k-1)/k} di du\right]^{k/(k-1)} (B^{*})^{-1} = \lambda.$$

Substitute this into the first-order condition, and we obtain

$$\text{(A1)}\quad Q_{iu} = \left[\int_{u=-\infty}^{u=+\infty}\int_{i=0}^{i=f(u)} \{e^{u}\}^{1/k} Q_{iu}{}^{(k-1)/k} di du\right]^{-k} \{e^{u}\} P_{iu}{}^{-k} (B^{*})^{k}.$$

Multiply P_{iu} on both sides of this equation, integrate the result over u and i, and substitute the definition of $\bar{P}$. Then we get

$$\text{(A2)}\quad [\int_{u=-\infty}^{u=+\infty}\int_{i=0}^{i=f(u)}\{e^{u}\}^{1/k}Q_{iu}^{(k-1)/k}didu\}]^{-k} = (B^{*}/\bar{P})^{1-k}.$$

Substitute this into (A1), and we obtain

$$Q_{iu} = (\frac{P_{iu}}{\bar{P}})^{-k}(\frac{B^{*}}{\bar{P}})e^{u}.$$

From the definition of $\bar{Y}$, (A2) implies

$$(\bar{Y})^{1-k} = (B^{*}/\ \bar{P})^{1-k} \quad \text{and } \bar{P}\bar{Y} = B^{*}.$$

(ii) The second step. The choice between consumption and real balances.

$$\text{Max}\quad (\bar{Y})^{\zeta}(\frac{\tilde{M}}{\bar{P}})^{1-\zeta}\{\zeta^{\zeta}(1-\zeta)^{1-\zeta}\}^{-1}\ \text{s.t.}\quad \bar{P}\bar{Y} + \tilde{M} = B.$$

Because of the Cobb-Douglas nature of the utility, we obtain

$$\bar{Y} = \zeta\frac{B}{\bar{P}}\ ,\ \tilde{M} = (1-\zeta)\frac{B}{\bar{P}}\ ,\ \text{and } \bar{Y}^{\zeta}(\frac{\tilde{M}}{\bar{P}})^{1-\zeta}\{\zeta^{\zeta}(1-\zeta)^{1-\zeta}\}^{-1} = \frac{B}{\bar{P}}.$$

<u>The Derivation of the Optimal Pricing Formula</u>

If X is log-normally distributed, then we have $\log EX^{b} = b\cdot E\log X + (1/2)b^{2}\cdot V(\log X)$ (see Aitchson and Brown (1969)). This property is used repeatedly in this appendix.

(1) Price-Making Quantity-Taking

The first-order condition is

$$(1-k)(P_{iu})^{-k}e^{\alpha}E_{\bar{P}}\bar{P}^{\,k-2} = (-k)(\mu/\phi)P_{iu}^{\,-k(\mu/\phi)-1}e^{\alpha(\mu/\phi)}E_{\bar{P}}(\bar{P})^{(k-1)(\mu/\phi)},$$

which implies, under our expectational assumptions,

$$\log(k-1)-kp_{iu} + \alpha + (k-2)e(\bar{p}|\Omega) + \frac{1}{2}(k-2)^2V(\bar{p}|\Omega)$$

$$=\log k+\log(\mu/\phi)-\{1+k(\mu/\phi)\}p_{iu}+\alpha(\mu/\phi)+(k-1)(\mu/\phi)e(\bar{p}|\Omega)+\frac{1}{2}\{(k-1)(\mu/\phi)\}^2V(\bar{p}|\Omega).$$

Rearranging terms, we obtain the expression in the text.

(2)Quantity-Making Price-Taking

The first-order condition is simply

$$(1-\frac{1}{k})Q_{iu}^{\,-(1/k)}\{E_{\bar{P}}(\bar{P})^{-(1/k)}\}(e^{\alpha})^{(1/k)} = \mu/\phi\ Q_{iu}^{\,(\mu/\phi)-1},$$

which implies

$$\log\frac{k-1}{k} - \frac{1}{k}q_{iu} - \frac{1}{k}e(\bar{p}|\Omega) + \frac{1}{2}(\frac{1}{k})^2V(\bar{p}|\Omega) + \frac{1}{k}\alpha = \log(\mu/\phi) + \{(\mu/\phi)-1\}q_{iu}.$$

Rearranging terms, we obtain the expression in the text.

Equilibrium Characterization under Complete Information

The individual pricing formula (11) is valid in the complete-information case. Consequently we obtain

$$p_u^* = \frac{1}{1+c_1k}a^* + \frac{c_1}{1+c_1k}\alpha + (1-\frac{c_1}{1+c_1k})\ \bar{p}^* \text{ where } a^*= \log(1+c_1)+\log\{k/(k-1)\},$$

which implies

$$p_u^* - \bar{p}_u^* = \rho^* u \text{ where } \rho^* = \frac{c_1}{1+c_1 k}.$$

Consequently p_u^* is normally distributed with mean $\bar{p}_u^*$ and variance $\rho^{*2}\sigma_u^2$, implying that $u + (1 - k)p_u^*$ is normally distributed with mean $(1 - k)\bar{p}_u^*$ and variance $\{1 + (1 - k)\rho^*\}^2\sigma_u^2$. Thus the price level $\bar{P}^*$ is the expectation of the log-normally distributed random variable $\exp[u + (1 - k)p_u^*]$, times $1/(1 - k)$. Then the log of $\bar{P}^*$, $\bar{p}^*$, is

$$\bar{p}^* = \bar{p}_u^* - z(\rho^*) \text{ where } z(\rho^*) = \frac{\{1-(k-1)\rho^*\}^2}{2(k-1)} \sigma_u^2.$$

It is straightforward to prove from the above relations that

$$\bar{p}^* = \frac{1}{c_1} a^* + h + m - \frac{1+c_1 k}{c_1} z(\rho^*).$$

Thus the long-run $\bar{p}^*$, denoted by $\bar{\bar{p}}^*$, is

$$\bar{\bar{p}}^* = \int_{m=-\infty}^{m=+\infty} \bar{p}^* g(m)dm = \frac{1}{c_1} a^* + h_1 - \frac{1+c_1 k}{c_1} z(\rho^*).$$

Rational Expectations under Price-Making Quantity-Taking

Let the firm assume

$$p_u - \bar{p}_u = \rho u \text{ and } e(\bar{p}|\Omega) = J + K(\alpha - h_1).$$

Then we obtain as in the complete information case

$$\bar{p} = \bar{p}_u - z(\rho).$$

Under rational expectations, we have

$$e(m|\Omega) = \theta(\alpha - h_1) \text{ where } \theta = \sigma_m^2/(\sigma_m^2 + \sigma_u^2), \text{ and}$$

$$V(m|\Omega) = E[\{m-e(m|\Omega)\}^2] = \theta\sigma_u^2 = (1 - \theta)\sigma_m^2.$$

Using the above results, we obtain $e(\bar{p}|\Omega)$ and $V(\bar{p}|\Omega)$ in the following way.

First, insert the above formula of $e(\bar{p}|\Omega)$ into the individual optimal price formula (20) and average it over u. Second, substitute the resulting expression into the $\bar{p}$ equation (19). Finally, apply $e(\cdot|\Omega)$ on both sides, and collect terms in order to get the expressions for J and K. The value of ρ is obtained immediately from the resulting price equation. This procedure gives the results in the text. As for $V(\bar{p}|\Omega)$, apply $V(\cdot|\Omega)$ on both sides of the $\bar{p}$ equation (19), and substitute the expression of $V(m|\Omega)$ above into the resulting expression. Then we get the expression in the text.

Rational Expectations under Quantity-Making Price-Taking

As in the case of price-making quantity-taking, let the firm assume

$$p_u' - \bar{p}_u' = \rho' u \text{ and } e(\bar{p}'|\Omega) = L + M(\alpha - h_1).$$

First, insert the optimal quantity formula (32) into the individual price equation (31). Second, substitute the above formula of $e(\bar{p}'|\Omega)$ into the resulting individual price equation and average it over u. Third, substitute the resulting expression into the $\bar{p}'$ equation (19). Finally, apply $e(\cdot|\Omega)$ on both sides, and collect terms in order to get the expressions for L and M. The value of ρ' is obtained immediately from the resulting price equation. This procedure gives the results in the text. As for $V(\bar{p}'|\Omega)$, apply $V(\cdot|\Omega)$ on both sides of the resulting $\bar{p}$ equation, and substitute $V(m|\Omega)$ into the resulting expression. Then we get the result in the text.

NOTES

1. In fact, the cost of information is likely to be larger in this heterogeneous-good market than in the homogeneous-good market which the information economics usually assumes.

2. Phelps and Winter in the Phelps volume take a different approach, which is often called as customer-flow dynamics. See Nishimura (1988b) for implications on price rigidity of this alternative approach.

3. Consider for example a market of hotel services with homogeneous consumers. There are many hotels, which are rather close substitutes of one another. Suppose initially that all hotels pledge their prices and satisfy the demand. Suppose then that one hotel does not make such a pledge. Then consumers have to form expectations about the hotel's actual price and availability. Expectation formation involves information gathering and processing, which are not trivial for the consumers. Moreover, there are also substantial visiting costs. It is usually painful to search for another hotel after visiting one hotel and find no-vacancy sign there. If the substitution is relatively easy compared with the above informational costs, then the consumers do not dare to visit the no-pledge hotel, and go to other hotels making the pledge. Thus the no pledge means no customer. Then to make the pledge is the equilibrium strategy so long as the pledge yields non-negative profits.

4. Iwai (1981) analyzes the effect of a non-negligible production period in the framework of non-rational expectations. I assume rational expectations in this paper.

5. Hall (1980) asserts that this assumption is a plausible one for the short-run analysis of the United States economy.

6. To guarantee existence of an equilibrium, k should be restricted to greater than unity. I further restrict k, which should be greater than two.

The assumption that k > 2 corresponds to the standard one in the literature of monopolistic competition that the individual demand function is flatter than the market one. Under the latter assumption, the monopolistically competitive revenue function is steeper with respect to the firm's price than the corresponding monopolistic revenue function, in which the firm's price is always equal to the average price in the market. However, unlike the partial-equilibrium monopolistic competition literature in which the firm maximizes nominal profits, the firm in our macroeconomic model maximizes real benefits. The assumption here that k > 2 implies that the the monopolistically competitive real revenue function is steeper with respect to the firm's price than the corresponding monopolistic real revenue function.

7. It can be shown in the following analysis that the price-making (quantity-taking) strategy always yields positive profits so long as other firms make the pledge. Thus if (i) the representative consumer dislikes uncertainty about the price of the products and its availability and (ii) decides not to visit the firm which does not make the pledge, then to make the pledge is an equilibrium policy.

There are various reasons for the consumer to dislike uncertainty about the price, and especially, the availability. The marketing literature provides many examples in which customers prefer stable supply to low prices. Okun (1981) argues that uncertainty strains the consumer's decision capacity, which is not unlimited as the conventional consumer theory under uncertainty assumes. The literature of economics of information emphasizes the cost of resolving uncertainty, that is, the cost of information (see Nishimura (1988a)).

8. We have $\rho < 1/(k - 1)$ if and only if $\theta < (1 + c_1)/\{1 + c_1(k - 1)\}$. Thus increased relative price variability (an increase in ρ) increases the price level so long as k is not very large.

9. We have $z(\rho^*) - z(\rho) > 0$ if and only if $2(1 + c_1)(1 + c_1 k) > (2 + c_1 + c_1 k)\{1 + c_1(k - 1)\}\theta$. Thus if the variance of the firm-specific disturbance σ_u^2 is much larger than the variance of the aggregate demand disturbance (a small θ), which is likely in the real world (see Okun (1981)), the increased relative-price variability increases the price level more under incomplete information than under complete information.

10. Because this is a well-known property in the literature of optimal quantity of money, I do not pursue the issue here.

11. Numerical analysis shows that this formula is a relatively good approximation so long as σ_m^2 and σ_u^2 have realistic values compared with $\bar{\bar{y}}^o$.

12. If c_1 is very large, there are perverse cases in which an increase in k increases the welfare loss.

13. Because of the physical limit, to satisfy all demand is not always possible.

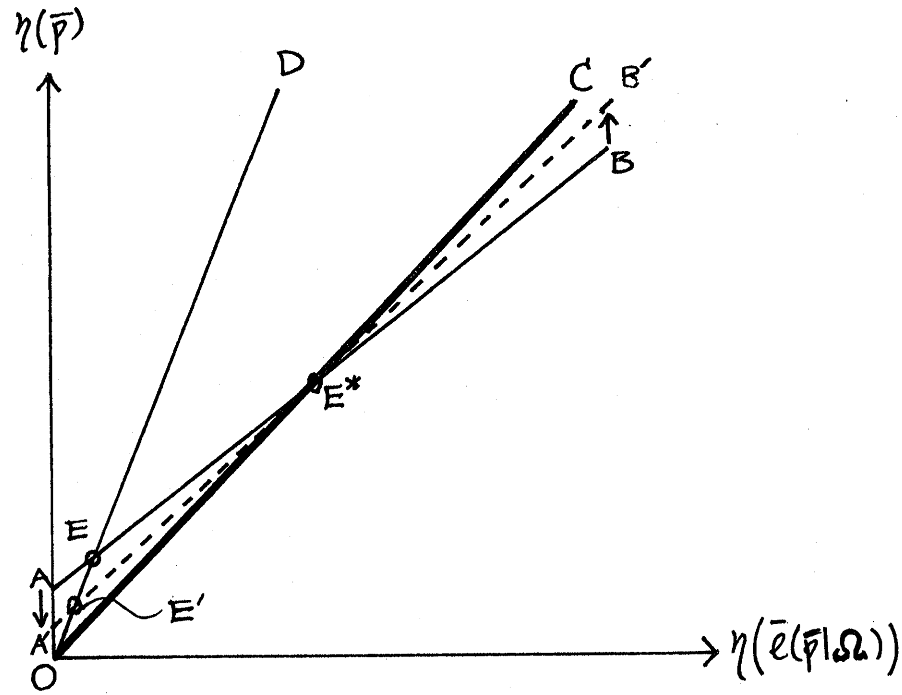

FIGURE 1

Price-Making Equilibrium:

Effect of Increased Competition

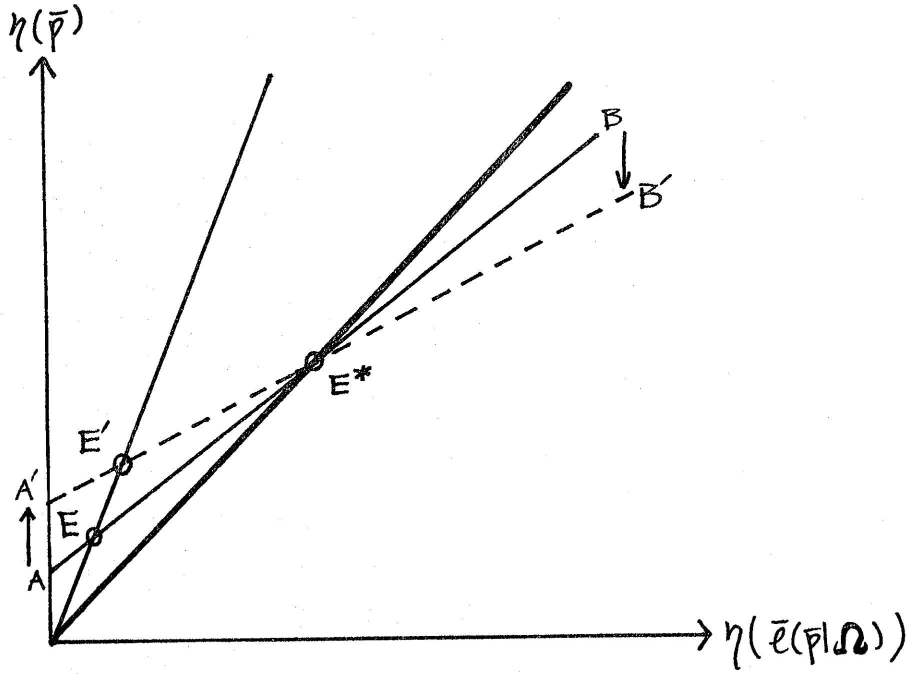

FIGURE 2

Price-Making Equilibrium:

Effect of Less Elastic Supply

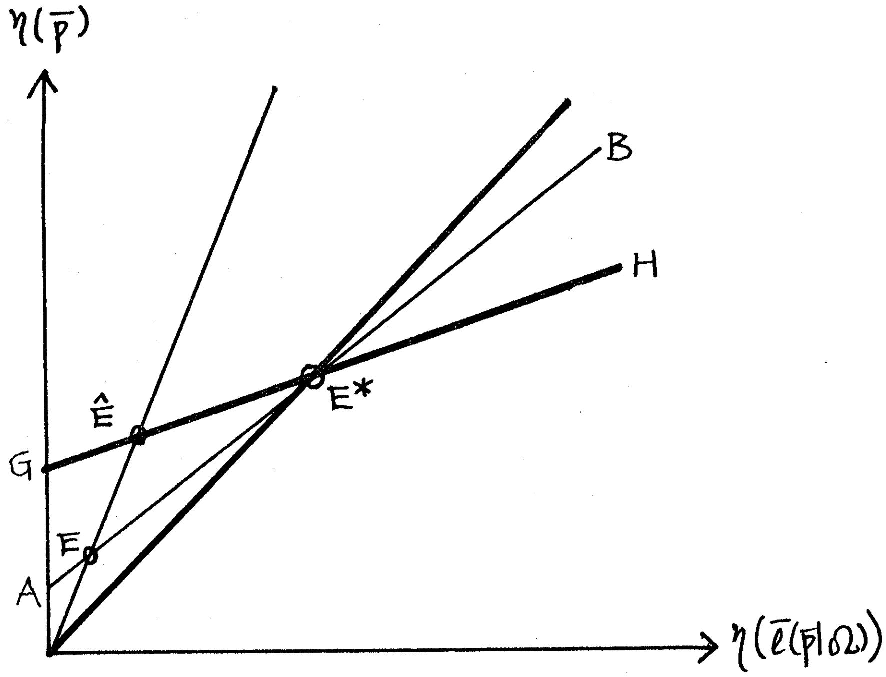

FIGURE 3

Quantity-Making Equilibrium

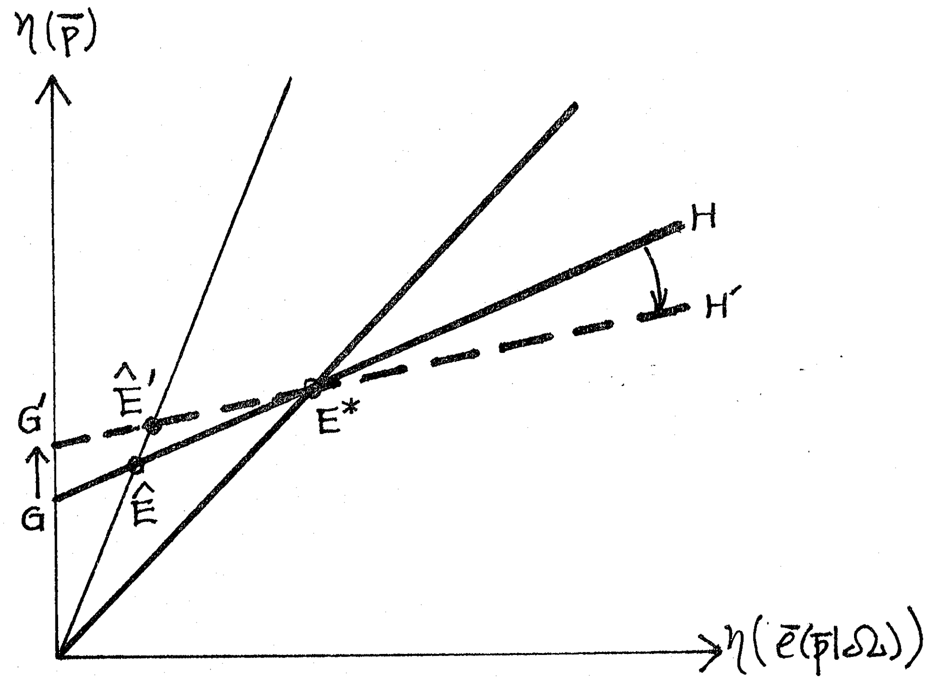

FIGURE 4

Quantity-Making Equilibrium:
Effects of Increased Competition
and Less Elastic

Figure 5
Price-Making Quantity-Taking

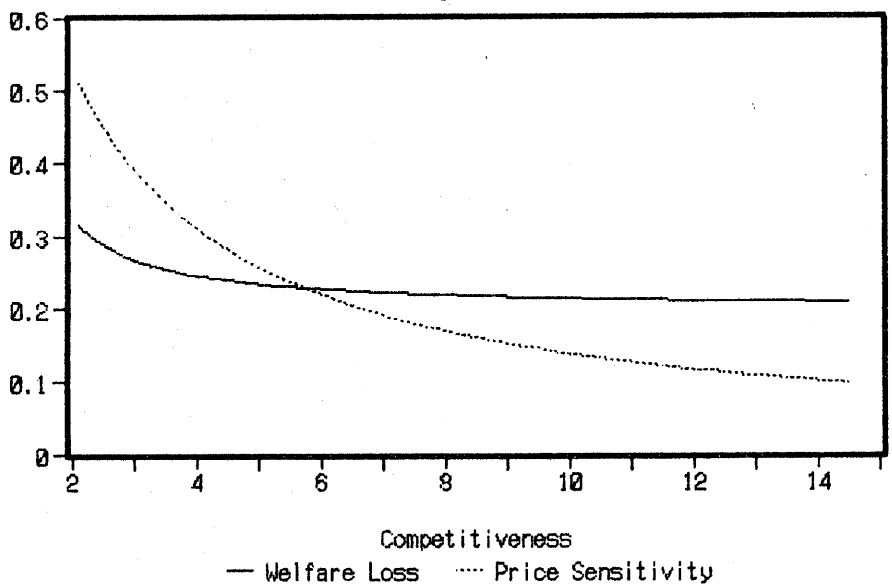

Figure 6
Quantity-Making Price-Taking