89-F-1

INDEXATION AND MONOPOLISTIC COMPETITION IN LABOR MARKETS

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February 1989

PREPARED UNDER
THE PROJECT ON MACROECONOMICS
RESEARCH INSTITUTE FOR THE JAPANESE ECONOMY

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January 1987

Revised December 1987

Second Revision May 1988

Third Revision January 1989

ABSTRACT

This paper investigates macroeconomic implications of monopolistic competition in labor markets. Predetermined wage contracts with cost-of-living adjustment are assumed. Although full indexation always insulates a perfectly competitive economy from nominal shocks, it does not insulate a monopolistically competitive economy from nominal shocks. In monopolistically competitive labor markets, complete insulation is achieved under less than full indexation. Price uncertainty affects nominal wages and thus output. Under full indexation, price uncertainty reduces the unconditional mean of output, while under no indexation price uncertainty is likely to increase the unconditional mean of output.

* I am indebted to the Editor and anonymous referees of the Review for their comments and suggestions on earlier versions of this paper.

1. INTRODUCTION

In recent years, considerable attention has been focused on monopolistically competitive macroeconomic models. Hart (1982), Blanchard and Kiyotaki (1987) and others investigate in a monopolistically competitive framework such macroeconomic problems as underemployment, multipliers, and optimal policy rules. They find that the monopolistically competitive macroeconomic models are characterized by "macroeconomic demand externality." This macroeconomic externality is sufficient to cause underemployment and "Keynesian-type multiplier effects" in such models.

Monopolistic competition under imperfect information is investigated in product markets by Andersen (1985) and Nishimura (1986, 1988a, 1988b). It is shown that product market monopolistic competition contributes to the rigidity of prices to demand shocks. Under imperfect information, increased competition among firms makes prices more rigid to demand shocks.

The purpose of this paper is to investigate labor market monopolistic competition under imperfect information. Following the literature of labor contracts and indexation (see Fischer (1977) and Gray (1976)), I assume labor contracts with predetermined wages and cost-of-living adjustment. This "long-run" nature of wage contracts is often observed in many industrialized economies and rationalized by the existence of substantial negotiation costs.

In this paper I show that the effects of indexation are very different between monopolistic competition and perfect competition. Full indexation completely insulates the economy from nominal shocks if labor markets are perfectly competitive (see Fischer and Gray). However, under monopolistic competition, full indexation does not at all insulate the economy from nominal shocks. Complete insulation is achieved by less than full indexation. Full indexation makes price uncertainty reduce the unconditional mean of output under monopolistic competition in labor markets, whereas under perfect competition full indexation renders the output level independent of price uncertainty. Moreover, these characteristics of labor market monopolistic competition do not depend on the degree of competition among labor unions. Thus, the economy with monopolistically competitive labor markets does not converge to the economy with perfectly competitive labor markets, even if competition in labor markets is very strong.

This paper is organized in the following way. A macroeconomic model with differentiated products and differentiated labor is presented in Section 2 (a choice-theoretic microfoundation of the model is given in the Appendix).[1] In order to concentrate our attention on labor markets, I assume product markets are perfectly competitive under perfect information. By contrast, labor markets are monopolistically competitive under imperfect information. One labor union controls one type of labor input and determines its wage rate. Labor markets are under imperfect information because of the nature of the assumed labor contracts. The general solution to the union's decision problem and the resulting labor market equilibrium are described in this section.

In Sections 3 through 5 I consider such special issues as the implications of full indexation, the degree of indexation which insulates the economy to nominal shocks, and the effects of price uncertainty on output under indexation. In Section 3, it is shown that full indexation does not insulate an economy having monopolistically competitive unions from nominal shocks, although it completely insulates an economy having perfectly competitive labor markets. Moreover, the monopolistically competitive economy has a negative correlation between money and output under full indexation.

The rate of cost-of-living adjustment that insulates the monopolistically competitive economy is derived in Section 4. The rate is less than unity, and depends on the convexity of preferences and technology. If the elasticity of marginal cost of production and that of marginal disutility of labor are large, then complete insulation is achieved by a small rate of cost-of-living adjustment. It is also shown that the monopolistically competitive economy has a positive money-output correlation only if the actual rate is smaller than the rate of complete insulation.

The effect of price uncertainty on the unconditional mean of output (which may be considered as the long-run level of output) is also investigated under monopolistic competition in Section 5. In an economy having monopolistically competitive labor unions, price uncertainty decreases wages and thus increases the unconditional mean of output if the actual rate of cost-of-living adjustment is smaller than the rate of complete insulation, while otherwise price uncertainty increases wages and decreases the unconditional mean of output. These results are compared with those in perfectly competitive labor markets.

In Section 6 I consider alternative specifications of monopolistically competitive unions. The objective function of the unions in Sections 3 through 5 is derived from a specific assumption on the preferences of consumers and workers. In this section, I investigate whether the results of Sections 3 through 5 are dependent on this particular assumption. I analyze two types of union behavior, which are commonly assumed in the literature. It is shown that the results of Sections 3 through 5 still hold with these more conventional specifications of union behavior. Finally, I conclude this paper in Section 7 with some remarks about the implications of this paper on business cycle theory.

2. THE MODEL

Consider an economy with differentiated products and differentiated labor. The model is based on Blanchard and Kiyotaki (1987). I incorporate disturbances in product demand, labor supply, and production technology into their model. In the following, the reduced-form model based on product and labor demand functions is analyzed, and the explicit analysis of its microfoundation is relegated to the Appendix.

Throughout this paper I assume perfect competition and perfect information in product markets. By contrast, labor markets are monopolistically competitive under imperfect information. Following Fischer (1977), I assume that (i) labor markets open before product markets, (ii) wage contracts are signed there, and (iii) employment is determined by firms after product markets open.[2] I assume that one union controls one type of labor input, and determines its wage rate. In the following analysis, all variables if not otherwise stated are in logarithms.

Wage Contracts

I assume that the following wage contracts including cost-of-living adjustment are signed in labor markets.

$$w = f + t\bar{p}, \tag{1}$$

where w is the ex post wage of individual labor, f is its base wage, $\bar{p}$ is the price level (the average price of differentiated products), and t is the exogenous cost-of-living adjustment parameter, satisfying $1 \geq t \geq 0$. The union determines the base wage f. The degree of indexation, t, is assumed to be historically given. Then the average ex post wage $\bar{w}$ is

$$(2)\qquad \bar{w} = \bar{f} + t\bar{p},$$

where $\bar{f}$ is the average base wage.

Product Markets

The demand for individual products is given by

$$(3)\qquad q = -k(p - \bar{p}) + \bar{y} + u,$$

where $k > 1$ is the own-price elasticity of product demand, p is the product's price, $\bar{y}$ is the average product demand, and u is the product-specific demand disturbance.

The average product demand is

$$(4)\qquad \bar{y} = m - \bar{p},$$

where m is the economy-wide nominal money supply disturbance. The disturbances m and u are assumed to be normally distributed, satisfying $Em = Eu = Emu = 0$, $Em^2 = \sigma_m^2$ and $Eu^2 = \sigma_u^2$. I assume perfect information in product markets, so that both m and u are observable.

The firm employs all types of labor in order to produce one type of product. The labor cost to the individual firm is given by

(5) $c = \bar{w} + \ell$, where $\ell = -\log(c_1 + 1) + (c_1 + 1)q$,

in which $\bar{w}$ is the average wage determined in (2), and ℓ is the labor input index (total labor input) of the firm. The term c_1 is the elasticity of the labor input index to output. I assume $c_1 > 0$, which implies decreasing returns to scale. The term $-\log(c_1 + 1)$ is a convenient normalization factor.

The firm's real profit, $\exp(\pi)$, is

(6) $\exp(\pi) = \exp(-\bar{p})\{\exp(p)\exp(q) - \exp(c)\}$.

The firm maximizes (6) with respect to q subject to (5) and (1). This determines the supply of the products, q^s. It is straightforward to show from the first-order condition of optimality that the supply is

(7) $q^s = \frac{1}{c_1}(p - \bar{w}) = \frac{1}{c_1}(p - t\bar{p} - \bar{f})$.

The equilibrium price is, from $q = q^s$,

(8) $p = (1 + c_1 k)^{-1}[\{t + c_1(k - 1)\}\bar{p} + \bar{f} + c_1 m + c_1 u]$.

Consequently the price level is

(9) $\bar{p} = \frac{\bar{f}}{1 - t + c_1} + \delta^* m$, where $\delta^* = \frac{c_1}{1 - t + c_1}$.

Labor Markets

The demand for individual labor has the form:

$$(10) \qquad n = - r(w - \bar{w}) + \bar{n} + v,$$

where r is the own-wage elasticity of labor demand, which satisfies $r > 1$, $\bar{n}$ is the average labor demand, and v is the type-specific labor demand disturbance. The disturbance v stems from productivity disturbances in the production function.

The average labor demand is[3]

$$(11) \qquad \bar{n} = - \log(c_1 + 1) + (c_1 + 1)\bar{y}.$$

Thus, we have the following individual labor demand:

$$(12) \qquad n = - r(w - \bar{w}) - \log(c_1 + 1) + (c_1 + 1)(m - \bar{p}) + v.$$

A worker supplying one type of labor has the following objective function:

$$(13) \qquad \exp(\rho) = \exp(w - \bar{p})\exp(n) - \exp(z).$$

Here z represents the disutility of labor such as

$$(14) \qquad z = - \log(z_1 + 1) + (z_1 + 1)n + \beta,$$

where z_1 is the elasticity of marginal disutility of labor. Here I assume that $z_1 > 0$, which implies increasing marginal disutility. The term $-\log(c_1 + 1)$ is a convenient normalization factor. The term β is the individual labor disturbance, which consists of the economy-wide labor supply disturbance, s, and the type-specific labor supply disturbance, x.

$$(15) \qquad \beta = s + x.$$

The random variables v, s, and x, together with m, are assumed to have the following characteristics. Random variables v, s, and x are normally distributed, satisfying $Ev = Es = Ex = Emv = Esx = Ems = Emx = Evx = Esv = 0$; $Ev^2 = \sigma_v^2$, $Es^2 = \sigma_s^2$, and $Ex^2 = \sigma_x^2$. I assume that σ_s^2 is sufficiently large compared with σ_m^2.[4]

The Union's Decision Problem

I assume the union's objective function is the same as that of its workers. Thus, the union maximizes $\hat{E}\{\exp(\rho)\}$ with respect to f, where $\hat{E}$ is the expectation operator with respect to the union's subjective distribution of $\bar{p}$. The union is endowed with rational expectations. The union assumes that $\bar{p}$ is normally distributed with mean $e(\bar{p}|\Omega_u)$ and variance $V(\bar{p}|\Omega_u)$, where $e(\bar{p}|\Omega_u)$ is the linear least squares regression of $\bar{p}$ on information Ω_u available to the union, and $V(\bar{p}|\Omega_u)$ is its error variance.

Let us now consider the information set Ω_u of the union at the time it determines its base wage. I assume that the union can observe the average base wage $\bar{f}$. In addition, the union is assumed to know the individual labor supply disturbance β, and the following individual labor demand disturbance ξ.

$$(16) \qquad \xi = (c_1 + 1)m + v.$$

However, the union cannot observe s, x, m, and v independently. Thus, Ω_u includes β, ξ and $\bar{f}$.

The optimal base-wage formula derived from the first-order condition is

$$(17) \qquad f = \frac{z_1 r}{1+z_1 r}(\bar{f} + \frac{\hat{a}_u + \beta + z_1\xi}{z_1 r}) + (1 - \frac{z_1 r}{1+z_1 r})\{1 - t - z_1(c_1+1)\}e(\bar{p}|\Omega_u),$$

where

$$(18) \quad \hat{a}_u = a_\ell^* + \log\frac{r}{r-1} - \frac{1}{2}\{1 - t - z_1(c_1+1)\}\{(z_1+2)(c_1+1) + (1-t)\}V(\bar{p}|\Omega_u),$$

in which

$$(19) \qquad a_\ell^* = - z_1\log(c_1+1).$$

The above optimal base-wage formula implies that if $1 - t - z_1(c_1 + 1) > 0$, then the base wage is raised when $e(\bar{p}|\Omega_u)$ is increased. Otherwise, an increase in the expected price lowers the base wage. Because we have

$$z_1\xi - z_1(c_1 + 1)e(\bar{p}|\Omega_u) = z_1(c_1 + 1)e(m - \bar{p}|\Omega_u) - z_1 e(v|\Omega_u),$$

(17) can be rewritten as

$$(20) \quad f = \frac{z_1 r}{1 + z_1 r}\{\bar{f} + \frac{\hat{a}_u + \beta}{z_1 r}\}$$

$$+ \left(1 - \frac{z_1 r}{1 + z_1 r}\right)\{(1 - t)e(\bar{p}|\Omega_u) + z_1(c_1 + 1)e(m - \bar{p}|\Omega_u) + z_1 e(v|\Omega_u)\}.$$

On the one hand, because the real wage is proportional to the reciprocal of the average price, its increase clearly puts upward pressure on the base wage for a given level of employment. This effect is represented by the first term in the second curly bracket in (20). On the other hand, an increase in the average price implies a decrease in aggregate demand through a reduction in real balances, so that the base wage should be cut in order to maintain employment. The second term in the second curly bracket in (20) shows this effect. The relative magnitudes of these conflicting forces determine whether an increase in the expected price raises the base wage or not.

If marginal disutility of labor increases rapidly as output increases ($z_1(c_1+1)$ is large), the union gives employment stability the highest priority. Then the incentive to reduce the base wage dominates the incentive to increase it, so that an increase in $e(\bar{p}|\Omega_u)$ decreases the base wage. In this case, the union is more concerned with the level of employment than the base wage (employment-concerned union). By contrast, if $z_1(c_1+1)$ is small, then it puts more weight on the base wage than employment (base-wage-concerned union).

In addition to z_1 and c_1, the degree of indexation (t) also determines whether the union is employment-concerned or base-wage-concerned. If t is increased, pressure on the base wage to keep the real wage is decreased. Then the union has more leeway to keep the level of employment. Thus, the overall effect depends on the sign of $1 - t - z_1(c_1 + 1)$. If this is positive, then the union is base-wage-concerned. Otherwise, it is employment-concerned. Note that in the case of full indexation ($t = 1$), the union is unambiguously employment-concerned.

Using the above structure of the economy and information contained in ξ (16), the firm can calculate $e(\bar{p}|\Omega_u)$ from (9).

$$(21) \qquad e(\bar{p}|\Omega_u) = \frac{\bar{f}}{1 - t + c_1} + \delta^* \phi \xi,$$

where

$$(22) \qquad \phi = (c_1+1)\sigma_m^2/\{(c_1+1)^2\sigma_m^2 + \sigma_v^2\}.$$

Then we obtain the following average price and quantity equations for the economy.

$$(23) \quad \bar{p} = \Xi(\hat{a}_u) + \Upsilon_u(t)\cdot m + \Theta\cdot s, \text{ and } \bar{y} = -\Xi(\hat{a}_u) + \{1 - \Upsilon_u(t)\}\cdot m - \Theta\cdot s,$$

where

$$(24) \qquad \Xi(\hat{a}_u) = \frac{\hat{a}_u}{c_1 + z_1 + c_1 z_1},$$

$$(25) \qquad \Upsilon_u(t) = 1 - \frac{\{1 - t - z_1(c_1 + 1)\}\{1 - \phi(c_1 + 1)\}c_1}{(1 - t + c_1)(c_1 + z_1 + c_1 z_1)},$$

and

$$(26) \qquad \Theta = \frac{1}{c_1 + z_1 + c_1 z_1}.$$

Monopolistic Competition and Perfect Competition

It may be worthwhile at this point to compare monopolistically competitive labor markets with perfectly competitive labor markets. Because of the predetermined wage, $\bar{p}$ is not observable to workers in perfectly competitive labor markets. However, information is perfect except for $\bar{p}$. The worker can observe β, f and $\bar{f}$. Thus the worker's information set Ω_W includes β, f, and $\bar{f}$.

The worker maximizes $\hat{E}\{\exp(\rho)\}$ with respect to n (see (13)), where $\hat{E}$ is the expectation operator with respect to the worker's subjective distribution of $\bar{p}$. The worker is also endowed with rational expectations. The worker assumes that $\bar{p}$ is normally distributed with mean $e(\bar{p}|\Omega_W)$ and variance $V(\bar{p}|\Omega_W)$.

Competitive labor supply is, from the first order condition of optimality,

$$(27) \qquad n^S = \frac{1}{z_1}\{f - (1 - t)e(\bar{p}|\Omega_W) + \frac{1}{2}(1 - t)^2 V(\bar{p}|\Omega_W) - \beta\}.$$

This shows that labor supply depends on the expected real wage $e(w - \bar{p}|\Omega_W) = f - (1 - t)e(\bar{p}|\Omega_W)$. Thus, an increase in the expected price always reduces labor supply. The equilibrium base wage in a local labor market is, from $n = n^S$,

$$(28) \quad f = \frac{z_1 r}{1+z_1 r}\{\bar{f} + \frac{\hat{a}_W + \beta}{z_1 r}\} + (1-\frac{z_1 r}{1+z_1 r})\{(1-t)e(\bar{p}|\Omega_W) + z_1(c_1+1)(m-\bar{p}) + z_1 v\},$$

where

$$(29) \qquad \hat{a}_w = a_\Omega^* - \frac{1}{2}(t - 1)^2 V(\bar{p}|\Omega_w).$$

Consequently, an increase in the worker's expected price unambiguously increases the base wage in the perfectly competitive case.

The average price and quantity equations under perfect competition are

$$(30) \qquad \bar{p} = \Xi(\hat{a}_w) + \Upsilon_w(t)\cdot m + \Theta\cdot s, \text{ and } \bar{y} = -\Xi(\hat{a}_w) + \{1 - \Upsilon_w(t)\}\cdot m - \Theta\cdot s,$$

where

$$(31) \qquad \Upsilon_w(t) = 1 - \frac{(1 - t)c_1\{1 - t + c_1 - (1 - t)\theta z_1(c_1 + 1)\}}{(1 - t + c_1)^2(c_1 + z_1 + c_1 z_1)},$$

in which

$$\theta = \frac{z_1(c_1 + 1)(1 - \delta^*)\sigma_m^2}{\{z_1(c_1 + 1)(1 - \delta^*)\}^2\sigma_m^2 + z_1^2\sigma_v^2}.$$

The worker in perfect competition only considers the real wage, whereas the union is concerned about the position of the "local" labor demand curve as well as the real wage. Because an increase in the expected price lowers the expected real wage, the perfectly competitive worker reduces his labor supply, and thus the equilibrium base wage increases. An increase in the expected price, however, reduces the expected aggregate demand through the real balance effect. Since aggregate demand is a major component of the local labor demand, the union has to take account of this demand-reducing effect of an increase in the general price level, in addition to the effect on the real wage. Thus, the overall effect of an increase in the expected price on the equilibrium base wage is ambiguous under monopolistic competition, depending on the relative magnitudes of the real wage effect and the local labor demand effect.

Using the results obtained in this section, I consider three special issues in the following sections. In Section 3, the implications of full indexation are analyzed. Section 4 derives the degree of indexation which insulates the economy from nominal shocks. Section 5 explains the interrelationship between the degree of indexation and the effect of price uncertainty on the unconditional mean of output.

3. DOES FULL INDEXATION INSULATE THE ECONOMY FROM NOMINAL DISTURBANCES?

In this section I analyze the case of full indexation ($t = 1$). I show that, in a monopolistically competitive economy, the monetary disturbance affects real variables even under full indexation, while full indexation completely insulates a perfectly competitive economy. The major difference between the case of perfect competition and monopolistic competition arises because the union is concerned about the position of the local labor demand as well as the real wage and hence forms expectations about the local shock as well as the aggregate nominal shock (general price level), whereas the worker in perfect competition only considers the real wage and forms expectations about the general price level. Full indexation makes the real wage and aggregate demand independent of the nominal shock. Thus, full indexation insulates the perfectly competitive economy. By contrast, in the monopolistically competitive economy, the union still has to infer the local shock. Because available information ξ (in (16)) does not give the union perfect information about v, there is the possibility of local-global confusion. This leads to imperfect insulation under full indexation.

Under full indexation, the price level and the demand for labor are, respectively,

$$(32) \qquad \bar{p} = \frac{\bar{f}}{c_1} + m \text{ and } n = -r(f - \bar{f}) - \log(c_1+1) - (1 + \frac{1}{c_1})\bar{f} + v.$$

Let us first consider perfectly competitive labor markets. Under full indexation, the worker's objective function is simply

$$(33) \qquad \exp(\rho) = \exp(f + n) - \exp\{-\log(z_1 + 1) + (z_1 + 1)n + \beta\}.$$

Thus, full indexation eliminates uncertainty. Then the equilibrium base wage is, from (28),

$$(34) \qquad f = (1+z_1 r)^{-1}[a_\ell^* + z_1\{r - \frac{c_1+1}{c_1}\}\bar{f} + z_1 v + \beta].$$

Consequently, the average base wage and the average output are, from (30),

$$(35) \qquad \bar{f} = (1 + \frac{z_1(c_1+1)}{c_1})^{-1}[a_\ell^* + s] \text{ and } \bar{p} = \Xi(a_\ell^*) + m + \Theta\cdot s.$$

Thus, full indexation makes the average base wage independent of m. Because the price level is completely flexible with respect to m for given $\bar{f}$, full indexation insulates the economy from the monetary disturbance.

In the monopolistically competitive case, the union's objective function is, under full indexation,

$$(36)\quad \exp(\rho) = \exp\{f - r(f - \bar{f}) - \log(c_1+1) - (1 + \frac{1}{c_1})\bar{f} + v\}$$

$$- \exp[-\log(z_1+1) + (z_1+1)\{- r(f - \bar{f}) - \log(c_1+1) - (1 + \frac{1}{c_1})\bar{f} + v\} + \beta].$$

This shows that, although full indexation eliminates uncertainty about the real wage and aggregate demand, uncertainty about the local shock v remains. The local shock v should be inferred from ξ.

The optimal base wage is, from (20),

$$(37)\qquad f = (1 + z_1 r)^{-1}[\hat{a}_u + z_1\{r - \frac{c_1+1}{c_1}\}\bar{f} + z_1 e(v|\Omega_u) + \beta], \text{ where}$$

$$\hat{a}_u = a_\Omega^* + \log\frac{r}{r-1} + \frac{1}{2}\{(z_1 + 1)^2 - 1\}V(v|\Omega_u).$$

Because $e(v|\Omega) = \{1 - (c_1+1)\phi\}\xi$, we obtain

$$(38)\qquad \bar{f} = (1 + \frac{z_1(c_1+1)}{c_1})^{-1}[\hat{a}_u + z_1\{1 - (c_1+1)\phi\}(1 + c_1)m + s].$$

Thus, under full indexation, the average base wage is no longer independent of m. It increases if m increases.

The dependence of $\bar{f}$ on m stems from local-global confusion in the monopolistically competitive union. Unlike the worker in a perfectly competitive labor market, the monopolistically competitive union has to form expectations about the local condition v relying on ξ. Because an increase in ξ is accompanied by an increase in m on the average, an increase in m raises the average forecast of v. Consequently, the average wage $\bar{f}$ increases when m increases.

The dependence of the base wage on the monetary disturbance implies imperfect insulation of the economy from the monetary disturbance. From (23) we obtain

$$(39) \qquad \bar{p} = \Xi(\hat{a}_u) + [1 + \frac{z_1(1+c_1)\{1-(c_1+1)\phi\}}{c_1+z_1+c_1z_1}]m + \Theta\cdot s.$$

Thus, the monetary disturbance affects output under full indexation in an economy with monopolistically competitive unions.

The direction of the monetary effect, however, is different from other models of non-neutral money. We obtain a negative money-output correlation, instead of a positive one. Because of perfect competition and perfect information in product markets, the price level is perfectly flexible to the monetary disturbance for a given $\bar{f}$ (the coefficient of m in (32) is unity). Then a positive correlation between $\bar{f}$ and m makes the price level excessively sensitive to m (the coefficient of m in (39) is larger than unity). Thus, local-global confusion under full indexation produces a negative money-output correlation.

4. COMPLETE INSULATION

In this and the next sections, I investigate the effect of money on real variables under general wage contract (1). In this section, I derive the rate of cost-of-living adjustment, t^*, that insulates the economy from nominal disturbances. In the next section, I analyze the effect of price uncertainty on the unconditional mean of real variables.

It is straightforward to show that the level of output is independent of m if

$$(40) \qquad t = t^* \equiv 1 - z_1(1 + c_1),$$

because $\Upsilon_u(t^*) = 1$ from (25). Thus t^* is the rate of cost-of-living adjustment that completely insulates the economy from the monetary disturbance.

Although ξ is always observable, it does not give the union perfect information about the shocks (m and v). Since m and v influence the base wage (and hence the price level) in a different way, observable ξ provides the union with only partial information about the price level. This is essential for the results in Section 3. The complete insulation is, however, ensured by a choice of indexation parameter which makes the local wage independent of the price level, and in this way the incomplete information about m and v does not preclude an insulation to the nominal shock. Thus, if $t = t^*$, we have $1 - t - z_1(1 + c_1) = 0$, which makes the optimal base wage independent of $e(\bar{p}|\Omega_u)$ (see (17)). Then (20) shows that the base wage depends on $z_1(c_1+1)e(m|\Omega_u) + z_1e(v|\Omega_u)$. However, we have $z_1(c_1+1)e(m|\Omega_u) + z_1e(v|\Omega_u) = z_1e\{(c_1+1)m + v|\Omega_u\} = z_1e(\xi|\Omega_u) = z_1\xi$. Here incomplete information about m and u does not matter, because m and u influence the base wage only through observable ξ.

Because $z_1 > 0$ and $c_1 > 0$, t^* is always smaller than unity. Thus, complete insulation needs less than full cost-of-living adjustment. Moreover, if z_1 and c_1 are large, t^* is small. In the extreme, if $z_1(1+c_1) > 1$, t^* is negative. Complete insulation needs a <u>negative</u> rate of cost-of-living adjustment in this case.

The sign of the correlation between money and output depends on whether t is greater or smaller than t^*. Note that under complete information, money is neutral. Under complete information, the individual base wage is

$$(41)\quad f = \frac{z_1 r}{1+z_1 r}\left(\bar{f} + \frac{\hat{a}_u^* + \beta + z_1\varepsilon}{z_1 r}\right) + \left(1-\frac{z_1 r}{1+z_1 r}\right)\{1 - t - z_1(c_1+1)\}\bar{p},$$

where

$$(42)\qquad \hat{a}_u^* = a_\ell^* + \log\{r/(r-1)\}.$$

Consequently, the price level is

$$(43)\qquad \bar{p} = \Xi(\hat{a}_u^*) + m + \Theta\cdot s.$$

Under complete information, the base wage f is always adjusted in such a way to make $\bar{p}$ just offset any change in m. Under incomplete information, however, the actual average price $\bar{p}$ in the above formula is replaced by the union's expectations $e(\bar{p}|\Omega_u)$. Because of local-global confusion, $e(\bar{p}|\Omega_u)$ is less sensitive to m than $\bar{p}$. If $t < t^*$, or equivalently, $1 - t - z_1(c_1+1) > 0$, an increase in the price level increases the base wage. Local-global confusion then implies that an increase in $\bar{p}$ induces a smaller increase in f under incomplete information than under complete information. Thus, $\bar{p}$ becomes less sensitive to m, and we obtain a positive correlation between money and output. By contrast, if $t > t^*$ $(1 - t - z_1(c_1+1) < 0)$, an increase in the price level decreases the base wage. Local-global confusion implies a larger increase in f because the base-wage-reducing effect of the price increase is now smaller under incomplete information. Thus the price level increases more under incomplete information than under complete information. Money and output are negatively correlated.

5. INDEXATION AND THE EFFECT OF PRICE UNCERTAINTY

An increase in monetary variance affects the unconditional mean of output by increasing price uncertainty in an economy with monopolistically competitive unions. From (23) we obtain

$$\bar{y}|_{m=s=0} = -\Xi(\hat{a}_u). \tag{44}$$

Because $\partial\hat{a}_u/\partial V(\bar{p}|\Omega_u) \neq 0$ (except for the case that $1 - t - z_1(c_1 + 1) = 0$) and $\partial\Xi/\partial\hat{a}_u > 0$, we have $\partial[\bar{y}|_{m=s=0}]/\partial V(\bar{p}|\Omega_u) \neq 0$. Thus, uncertainty about the <u>absolute</u> price level affects the unconditional mean of output. The direction of the effect depends on the degree of indexation t. If t is small so that the union is base-wage-concerned $(1 - t - z_1(c_1 + 1) > 0)$, increased uncertainty about the price level <u>increases</u> the unconditional mean of output. By contrast, if t is large so that the union is employment-concerned $(1 - t - z_1(c_1 + 1) < 0)$, the increased uncertainty <u>decreases</u> the unconditional mean of output.[5]

Whether price uncertainty increases or decreases the unconditional mean of output depends on the concavity/convexity of the first derivative of the objective function $\exp(\rho)$ with respect to the decision variable f. The first derivative is

(45) $\frac{\partial \exp(\rho)}{\partial f} = (1-r)\cdot\exp[(1-r)f-\log(c_1+1)+\xi+r\bar{f}-\{1-t+(c_1+1)\}\bar{p}]$

$$+ r\cdot\exp[(z_1+1)\{-rf-\log(c_1+1)+\xi\}+\beta+(z_1+1)r\bar{f}-(z_1+1)(c_1+1)\bar{p}].$$

Consequently, around $f = f^*$, which is the solution of $\partial\exp(\rho)/\partial f = 0$, we obtain

(46) $\frac{\partial^2}{\partial \bar{p}^2}\{\frac{\partial \exp(\rho)}{\partial f}\} = \{1 - t - z_1(c_1 + 1)\}\{(z_1 + 2)(c_1 + 1) + (1 - t)\}\Delta,$

where $\Delta = (1 - r)\cdot\exp[(1 - r)f^* - \log(c_1+1) + \xi + r\bar{f} - (1 - t + (c_1 + 1))\bar{p}] < 0$ because $r > 1$. If $1 - t - z_1(c_1 + 1) > 0$, then the first derivative is concave in $\bar{p}$. Thus, uncertainty about $\bar{p}$ decreases the marginal benefit of the base wage increase, so that the optimal base wage is reduced. Because a reduction in the base wage implies an increase in output, price uncertainty increases the unconditional mean of output if $1 - t - z_1(c_1 + 1) > 0$. A symmetric result is obtained if $1 - t - z_1(c_1 + 1) < 0$. In this case, price uncertainty decreases the unconditional mean of output. Specifically, under full indexation ($t = 1$), price uncertainty unambiguously decreases the unconditional mean of output.

It may be worthwhile to compare monopolistically competitive labor markets with perfectly competitive labor markets. Recall competitive labor supply is determined by (27). This is a familiar Lucas supply function if $t = 0$. The usual practice is to ignore the variance term in (27).[6] However, this conceals the importance of price uncertainty on labor supply. Using this labor supply function, we obtain the unconditional mean of the perfectly competitive output as

(47) $$\bar{y}|_{m=s=0} = - \Xi(\hat{a}_w), \text{ where } \hat{a}_w = a_\Omega^* - \frac{1}{2}(t - 1)^2 V(\bar{p}|\Omega).$$

Thus, an increase in price uncertainty does not influence the unconditional mean of output under full indexation ($t = 1$). Under less than full indexation, price uncertainty unambiguously increases the unconditional mean of output.

The first derivative of the worker's objective function with respect to his decision variable n^s is

(48) $$\frac{\partial \exp(\rho)}{\partial n^s} = \exp\{f - (1 - t)p + n^s\} - \exp\{(z_1 + 1)n^s + \beta\}.$$

Consequently, we have

(49) $$\frac{\partial^2}{\partial \bar{p}^2}\{\frac{\partial \exp(\rho)}{\partial n^s}\} = (1 - t)^2 \exp\{f - (1 - t)p + n^s\} > 0.$$

Thus, the first derivative is strongly convex in $\bar{p}$ if $t < 1$. Under less than full indexation, price uncertainty unambiguously increases the marginal benefit of labor supply. Consequently, labor supply increases, which reduces the equilibrium base wage and hence increases the equilibrium output.[7]

6. ALTERNATIVE SPECIFICATIONS OF LABOR UNION BEHAVIOR

The objective function of the unions in previous sections is not conventional in the recent union literature, though it can be derived as the utility of its members (see the Appendix). In this section I analyze more conventional objectives of the unions, and discuss whether the same results would be found with such objectives. I consider the case of full indexation in this section.

Following Oswald (1985), I consider two major specifications of union preferences. The first approach adopts the Stone-Geary functional form:

$$\exp(\rho) = \{\exp(w - \bar{p}) - \exp(\hat{h})\}^{b}\{\exp(n + \beta) - \exp(\hat{n})\}^{d}, \tag{50}$$

where $0 < b < 1$ and $0 < d < 1$. Here $\hat{h}$ and $\hat{n}$ are "reference" levels of real wages and employment. As in the previous sections, β represents a shock in the union preference function. The second specification of union preferences is the expected utility with the possibility of random layoffs such as

$$\exp(\rho) = \exp\{g(w - \bar{p})\}\exp(n - \hat{\ell})\exp(\beta) + \exp(\hat{z})\{1 - \exp(n - \hat{\ell})\exp(\beta)\}, \tag{51}$$

where $0 < g < 1$. Here $\exp\{g(w - \bar{p})\}$ is the utility of an employed worker, n is the number of employed workers, $\hat{\ell}$ is the membership of the union, and $\exp(\hat{z})$ is the utility of an unemployed worker. Thus $\exp(n - \hat{\ell})$ is the probability of employment if layoff is distributed purely randomly, so long as the constraint $n \leq \hat{\ell}$ is not binding. Here again β represents a shock in the union preferences.[8]

Let us first consider the case of Stone-Geary union preferences (50). Suppose that $\exp(\hat{h}) = 0$ and $b > dr$. Then the optimal base wage is approximately [9]

$$(52) \qquad f = \frac{1}{r}[\log\frac{b-dr}{b} - \log(1+c_1) + \{r-(1+\frac{1}{c_1})\}\bar{f} + \beta - \hat{n} + e(v|\Omega_u)].$$

Because $e(v|\Omega_u)$ appears in the base wage formula, full indexation does not insulate the economy. A qualitatively similar result is also obtained in the general case with $\exp(\hat{h}) > 0$ as well as $\exp[\hat{n}] > 0$. Thus, the results in the previous sections hold true in this specification of union preferences.

Next, in the case of the expected-utility specification (51), the union's optimal base wage is approximately

$$(53) \qquad f = \frac{1}{g}\log\frac{r}{r-g} + \frac{1}{g}\hat{z}.$$

Because f is independent of $e(v|\Omega_u)$, full indexation completely insulates the economy.

This complete-insulation result, however, stems from the rather restrictive assumption that the constraint $n \leq \hat{\Omega}$ is never binding. In this case, the union's utility (51) is linear in labor supply. This property is essential to obtain complete insulation.[10]

If we allow that the constraint $n \leq \hat{\Omega}$ is binding in some cases,[11] the union's objective function is

$$(54) \qquad \exp(\rho) = \exp(\hat{z}) + \exp\{g(w - \bar{p})\}\cdot\min[1, \exp(n - \hat{\Omega})\exp(\beta)].$$

This shows that the union's utility is generally strictly concave in labor supply even under the random layoff scheme. We obtain in general incomplete insulation for utility functions which are strictly concave in labor supply. Thus, except for the case in which the union is certain that n is always less than $\hat{\ell}$, insulation is likely to be incomplete.

7. CONCLUDING REMARKS

In this paper I have compared under the framework of predetermined wages an economy having monopolistically competitive labor markets with an economy having perfectly competitive labor markets. It has been shown that full indexation might not insulate the monopolistically competitive economy from nominal disturbances, though it completely insulates the perfectly competitive economy. Price uncertainty has also been shown to influence the determination of nominal wages and hence output.

Monopolistic competition in labor markets, however, makes prices more sensitive to nominal demand shocks than perfect competition. Because of this property, output is negatively correlated with money under full indexation. Thus, complete insulation under monopolistic competition needs less than full indexation. In this sense, monopolistic competition in labor markets is not likely to contribute to the observed rigidity of prices and wages to nominal shocks. This result is in sharp contrast to the effect of monopolistic competition in product markets in Nishimura (1986) and Andersen (1985). They show that monopolistic competition in product markets does contribute to the rigidity of prices to nominal shocks.

Monopolistic competition in labor markets, however, makes wages and thus prices rigid to nominal shocks if the informational separation of monopolistically competitive unions is introduced as an additional source of imperfect information. In this case, the average wage is assumed to be unobservable. Then local-global confusion makes individual wages less sensitive to labor demand conditions, and ultimately, aggregate nominal demand conditions. Consequently, prices become insensitive to nominal shocks. This type of labor market is analyzed in Nishimura (1987). It is shown there that if competition among labor unions is strong, then the rigidity-enhancing effect of monopolistic competition dominates its flexibility-enhancing effect.

Finally, a remark on the rational expectations assumption may be due. The assumption that unions have information about the structure of the economy may seem a heroic assumption at first glance. However, what we need in the analysis is not complete knowledge, but some reliable knowledge about firms and other unions (uncertainty surrounding such knowledge can be treated by adding observation errors). Under imperfect competition, knowledge about customers and rivals is vital. In this case it is reasonable to assume unions have some reliable knowledge about firms and other unions. In such an economy this assumption is not so unreasonable.

NOTES

1. See the last part of this paper.

2. Although such contracts are widely observed, they are <u>ex post</u> inefficient under imperfect information. The analysis of this paper, like other studies assuming this type of contract, depends on the existence of this inefficiency. However, the use of such contracts may be justified under asymmetric information between the firm and the union, because wage contracts are incentive compatible.

3. The average labor demand $\bar{n}$ is equal to the average labor input, $\bar{\ell}$. From (5), we have $\bar{n} = \bar{\ell} = -\log(c_1+1) + (c_1+1)\bar{q}$. From this and the fact that $\bar{y} = \bar{q}$, we obtain the expression in the text.

4. Formally, I assume $\sigma_s^2 << \sigma_m^2$, so that the average base wage, which is observable in the labor markets, gives little information about m. This assumption is made only for the sake of analytic simplicity. The results of this paper do not depend on this rather unrealistic assumption. The main results of this paper still hold with little modification so long as σ_s^2 is positive. However, the derivation of rational expectations in general cases becomes complicated because we have to consider information about m contained in $\bar{f}$.

5. To put it more precisely, I consider the unconditional mean of the <u>log</u> of output here. If the stochastic structure of the economy is the same for a long time, the unconditional mean of output is equal to the long-run average of output. In this case the above argument implies that monetary variance affects the long-run level of output.

6. Usually, logEexp[x] is approximated by Ex.

7. However, the effect of uncertainty on the long-run level of output is in general ambiguous in models allowing the intertemporal substitution effect.

8. The way β enters the utility functions (50) and (51) is only one of many possibilities of describing labor supply disturbances. However, the results of this section hold true so long as β influences the optimal base wage.

9. Let $\hat{E}f(v) = 0$ be the first order condition of optimality, where $\hat{E}$ is the expectation operator with respect to the union's subjective distribution of v. If $\hat{E}f(v)$ is approximated by $f(\hat{E}v)$, then we obtain the base wage formula in the text. This method yields a relatively good approximation to the short-run behavioral equations, though it may give misleading results in analyzing the long-run effect of price variability as explained earlier in the discussion of the Lucas supply function.

10. In fact, even in the framework of the previous sections, we obtain complete insulation if the union's utility is linear in labor supply. t^* is equal to unity if z_1 is equal to zero.

11. Under the assumption of log-normal distributions of m and v, there always exists the possibility of very large labor demand. In this case, the constraint $n \leq \Omega$ is likely to be binding.

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APPENDIX:

A MACROECONOMIC MODEL

WITH DIFFERENTIATED PRODUCTS AND DIFFERENTIATED LABOR INPUTS

The Representative Household

Suppose that there are (1) T_1 kinds of products, and (2) T_2 kinds of labor inputs. There are identical households owning firms' stocks and supplying labor inputs to the firms. The structure of the household's preferences are assumed to be such that (1) before the realization of disturbances in the preferences, all products and labor inputs are symmetric, respectively, but (2) after the realization, (a) the products can be grouped into n_1 types, within which products are symmetric, and (b) the labor inputs can be grouped into n_2 types, within which labor inputs are symmetric. I hereafter consider a symmetric case in which all symmetric products have the same price and the same production level, and all symmetric labor inputs have the same wages and the same employment level.

Specifically, I assume that the representative household's utility function is

$$\text{(A1)} \qquad \Psi = \{\zeta^{-\zeta}(1 - \zeta)^{-(1-\zeta)}\} (\bar{Y})^{\zeta} (\frac{\tilde{M}}{\bar{P}})^{1-\zeta} - D,$$

where the term $\zeta^{-\zeta}(1 - \zeta)^{-(1-\zeta)}$ is a normalization factor; $\bar{Y}$ is the aggregate consumption index:

$$\text{(A2)} \qquad \bar{Y} = T_1\{(\Sigma_{i=1}^{n_1} f_i \, U_i^{1/k} \, Q_i{}^{(k-1)/k})/T_1\}^{k/(k-1)};$$

$\tilde{M}$ is the end-of-the-period nominal money holdings; $\bar{P}$ is the price level associated with $\bar{Y}$:

$$\text{(A3)} \qquad \bar{P} = \{(\Sigma_{i=1}^{n_1} f_i U_i P_i^{1-k})/T_1\}^{1/(1-k)};$$

and D is the index of disutility of labor such as

$$\text{(A4)} \qquad D = T_2^{-1}\Sigma_{j=1}^{n_2} g_j \Delta_j N_j^{\mu}.$$

In (A2), f_i is the number of the products having U_i (I hereafter call them the products of type U_i), satisfying $\Sigma_{i=1}^{n_1} f_i = T_1$, and Q_i is the consumption of each of the products of type U_i. If U_i is equal to unity for all i, all products are perfectly symmetric. Thus U_i can be called the product-specific demand term. U_i is assumed to satisfy

$$\Sigma_{i=1}^{n_1}(\frac{f_i}{T_1})\log U_i = 0 \text{ and } \Sigma_{i=1}^{n_1}(\frac{f_i}{T_1})(\log U_i)^2 = \sigma_u^2.$$

In (A3) P_i is the price of the products of type U_i.

The term Δ_j in (A4) represents the labor supply term, which I assume consists of the economy-wide term S and the input-specific one X_j.

$$\Delta_j = S \cdot X_j.$$

Then in (A4) g_j is the number of the labor inputs having X_j (I hereafter call them the labor inputs of type X_j), satisfying $\Sigma_{j=1}^{n_2} g_j = T_2$; and N_j is the supply of each of the labor inputs of type X_j. X_j is assumed to satisfy

$$\Sigma_{j=1}^{n_2}(\frac{g_j}{T_2})\log X_j = 0 \text{ and } \Sigma_{j=1}^{n_2}(\frac{g_j}{T_2})(\log X_j)^2 = \sigma_x^{\,2}.$$

Thus the utility function is a composite of CES and Cobb-Douglas functions. The parameters k, θ and μ satisfy $k > 1$, $1 > \zeta > 0$, and $\mu > 1$.

The representative household's demand for each products is derived from the maximization of Ψ with respect to the level of consumption of each products and the level of real balances subject to the budget constraint

$$\text{(A5)} \qquad \Sigma_{i=1}^{n_1} f_i P_i Q_i + \tilde{M} = B,$$

where B is such that

$$B = \Sigma_{j=1}^{n_2} g_j \Lambda_j + \Sigma_{i=1}^{n_1} f_i \Pi_i + M.$$

Here, M is the beginning-of-the-period money holdings, Λ_j is wages of each of the labor inputs of type X_j, and Π_i is dividends from each firm producing the products of type U_i. Using the property of the CES and Cobb-Douglas functions, we can derive the demand Q_i for each of the products of type U_i and the demand for real balances. They are

$$\text{(A6)} \qquad Q_i = (\frac{P_i}{\bar{P}})^{-k}\,\bar{Y}(\frac{1}{T_1})U_i,\ \bar{Y} = \zeta\frac{B}{\bar{P}},\ \text{and}\ \frac{\tilde{M}}{\bar{P}} = (1 - \zeta)\frac{B}{\bar{P}}.$$

Substituting them into (A1), we obtain the representative household's indirect utility

(A7) $\Psi \equiv B/\bar{P} - (\frac{1}{T_2})\Sigma_{j=1}^{n_2} g_j\Delta_j N_j^{\mu}$.

Product Markets

I assume perfect competition and perfect information in product markets. The firm is a price taker, and all prices and wages are known. Without loss of generality, I assume that one product is produced by one firm.

(1) The Firm

The production function of the firm is

(A8) $$Q_i = [T_2\{(\Sigma_{j=1}^{n_2} g_j V_j^{1/r} L_{ij}^{(r-1)/r})/T_2\}^{r/(r-1)}]^{\phi},$$

where L_{ij} is the labor input of type X_j of the firm producing the product of type U_i. The parameters in (A8) satisfy $r > 1$ and $0 < \phi < \mu$. Thus the production function is also a composite of CES and Cobb-Douglas functions.

V_j represents the productivity term specific to the labor inputs of type X_j. (Thus I assume that the labor inputs of the same type have the same productivity disturbance. This assumption is made only for notational simplicity. The relaxation of this assumption is straightforward though notationaly very cumbersome.) V_j is assumed to satisfy

$$\Sigma_{j=1}^{n_2}(\frac{g_j}{T_2})\log V_j = 0 \text{ and } \Sigma_{j=1}^{n_2}(\frac{g_j}{T_2})(\log V_j)^2 = \sigma_v^2.$$

The firm maximizes the real benefits of its stockholders. Because the firm's stocks are owned by the representative household, the firm's objective is to maximize the representative household's utility with respect to its decision variables, Q_i and L_{ij}. Consequently, the firm's objective function is

$$\Psi = \frac{1}{\bar{P}}\{P_i Q_i - \Sigma_{j=1}^{n_2} g_j W_j L_{ij}\} + D' \tag{A9}$$

where D' is the term given to the firm. Thus the firm maximizes (A9) subject to (A8) and the wage rate W_j, taking D' as given.

As is well-known, this maximization takes two steps. The first step is to minimize wage payments taking Q_i as given. This yields

$$L_{ij} = \left(\frac{W_j}{\bar{W}}\right)^{-r} Q_i^{1/\Phi}\left(\frac{1}{T_2}\right)V_j \quad \text{and} \quad \Sigma_{j=1}^{n_2} g_j W_j L_{ij} = \bar{W} Q_i^{1/\Phi}, \tag{A10}$$

where

$$\bar{W} = [(\Sigma_{j=1}^{n_2} g_j V_j W_j^{(1-r)})/T_2]^{1/(1-r)}. \tag{A11}$$

The second step is to maximize

$$\frac{1}{\bar{P}}[P_i Q_i - \bar{W} Q_i^{1/\Phi}] \tag{A12}$$

with respect to Q_i. This maximization determines the supply of the i-th product, Q_i^s, such as $Q_i^s = [(\Phi P_i)/(\bar{P}\bar{W})]^{\Phi/(1-\Phi)}$.

(2) Equilibrium

The equilibrium conditions in product markets consist of (a) the monetary equilibrium condition $\tilde{M} = M$, and (b) the individual product market equilibrium condition $Q_i^S = Q_i$. Because the firm does not retain profits, we obtain from the monetary equilibrium condition

$$\text{(A13)} \qquad \bar{Y} = \frac{\zeta}{1-\zeta}\frac{M}{\bar{P}}.$$

Thus aggregate demand is proportional to initial real money holdings. The individual product market condition determines the price as a function of $\bar{P}$, $\bar{W}$, U_i and $\bar{Y}$.

Labor Markets

Labor markets open before product markets. Thus the participants in labor markets have only imperfect information about the condition of product markets. However, the firm is given the right to determine its employment level after product markets open. I consider (i) the perfectly competitive case and (ii) the monopolistically competitive case.

(1) Labor Demand

Let N_j be the demand for the labor input of type X_j such that $N_j = \Sigma_{i=1}^{n_1} f_i L_{ij}$. Define the aggregate labor demand index $\bar{N}$ such as:

$$\text{(A14)} \qquad \bar{N} = \Sigma_{i=1}^{n_1} f_i Q_i^{1/\phi}.$$

Then we obtain

$$\text{(A15)} \qquad N_j = V_j\left(\frac{W_j}{\bar{W}}\right)^{-r} \bar{N}\left(\frac{1}{T_2}\right) \text{ and } \bar{W}\bar{N} = \Sigma_{i=1}^{n_1} f_i \left(\Sigma_{j=1}^{n_2} g_j W_j L_{ij}\right).$$

Thus $\bar{W}\bar{N}$ is the total wage payments in the economy.

(2) Perfectly Competitive Labor Markets

The supply of the labor input of type X_j is determined by the representative household. The household maximizes its utility with respect to this type of labor. Thus the supply of the labor input of type X_j, N_j^s, is the solution of the maximization of the following expected utility

$$\text{(A16)} \qquad \hat{E}\,\Psi = \hat{E}\,\frac{1}{\bar{P}}\{W_jN_j\} - \frac{1}{T_2}\Delta_j N_j^{\mu} + D'',$$

where $\hat{E}$ is the expectation operator with respect to the worker's subjective distribution of $\bar{P}$, and D" is a constant term. Then equilibrium is determined by $N_j^s = N_j$.

(3) Monopolistically Competitive Labor Markets

In the monopolistically competitive case, the supply of one type of labor is controlled by one union. The union of type X_j, which controls the labor input of type X_j, sets the wage rate for the labor input in order to maximize the real benefits of its workers. Because labor inputs are supplied by the representative household, the union maximizes the representative household's utility. Consequently the j-th union's objective is to maximize (A16) with respect to W_j subject to the labor demand function (A15), where $\hat{E}$ is the expectation operator with respect to the union's subjective distribution.

Log-linear Log-normal Approximation

Retaining the above structure of the model, I use two types of approximation in this paper. The first is a log-linear approximation to the aggregate indices $\bar{P}$, $\bar{W}$, and $\bar{N}$. In the following let the lower case term be the log of the corresponding upper case term, for example, $\bar{p} = \log \bar{P}$, $p_i = \log P_i$, etc. Consequently, we have from (A3) that $\bar{p} = \{1/(1 - k)\}$

$\cdot[\log\{(1/T_1)\Sigma_{i=1}^{n_1} f_i \exp(u_i)\exp((1-k)p_i)\}]$. Take the first-order Taylor's expansion of this expression around $u_i = 0$ and $p_i = 0$ for all i. From this we obtain

$$\bar{p} = \Sigma_{i=1}^{n_1} (\frac{f_i}{T_1})p_i, \text{ because } \Sigma_{i=1}^{n_1}(\frac{f_i}{T_1})u_i = 0.$$

Similar procedures on (A11), (A2), and (A14) yield,

$$\bar{w} = \Sigma_{j=1}^{n_2} (\frac{g_j}{T_2})w_j, \ \bar{y} = \log T_1 + \Sigma_{i=1}^{n_1} (\frac{f_i}{T_1})q_i, \text{ and}$$

$$\bar{n} = (1/\Phi)\{\log T_1 + \Sigma_{i=1}^{n_1} (\frac{f_i}{T_1})q_i\} = (1/\Phi)\bar{y}.$$

The second approximation is a log-normal approximation to the distribution of U_i and X_j. Instead of assuming a discrete distribution for them, I assume that u = logU and x = logX are independent continuous random variables, whose distributions are normal. Thus we obtain (omitting subscripts) $\bar{p} = Ep$, $\bar{w} = Ew$, $\bar{y} = \log T_1 + Eq$, and $\bar{n} = (1/\Phi)\bar{y}$, where E is the expectation operator with respect to u and x. Then we get the log-linear log-normal model of the text with $c_1 = (1/\Phi) - 1$ and $z_1 = \mu - 1$, except for constant terms.