Journal of Institutional and Theoretical Economics

JITE

Zeitschrift für die gesamte Staatswissenschaft

Volume 150

1994

Wage Flexibility, Menu Costs, and Price Level Stickiness

by

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I consider the relation between wage determination and price level stickiness along the lines of the menu costs approach. I allow for flexible wages and a variable fraction of firms adjusting their prices in response to aggregate demand shocks. Strategic substitutability between firms arises for empirically plausible parameter values implying (1) a price elasticity of aggregate supply which is neither zero nor infinite and (2) unrealistically high menu costs. Efficiency wages as well as fixed wages imply that either all firms do or do not adjust prices. In both cases, menu costs required for fixed prices are quite small. (JEL: E 24, E 42, L 16)

1. Introduction

Among the stylized facts of business cycles is the positive correlation between real and nominal GNP. Keynesian economics attributes this finding to sticky wages and product prices. The literature labeled "New Keynesian" by Stanley FISCHER [1988] provides choice-theoretic underpinnings to this assumption.

AKERLOF and YELLEN [1985], MANKIW [1985], and PARKIN [1986] point out that fixed costs of price adjustment (menu costs) deter monopolistically competitive firms from adjusting prices to temporary cost or demand shocks. According to the envelope theorem, profits lost due to changed market conditions are independent from optimally chosen prices up to a first order approximation. Hence, even small menu costs may suffice to prevent price adjustment.

AKERLOF and YELLEN [1985], BALL and ROMER [1990], and BLANCHARD and KIYOTAKI [1987] present numerical examples of the size of profits (utility) lost in percent of revenue (real income) when prices remain fixed in response to a five or ten percent increase of money supply. Most of the cases show a loss of less than one-tenth of one percent.

These papers share two closely related implications. (1) Profits lost by a firm which does not adjust its price to a demand shock are an increasing function of the fraction of price-adjusting firms. Price decisions are characterized by strategic complementarity (COOPER and JOHN [1988]). (2) As a consequence, in a stable Nash equilibrium with a given size of menu costs, either all firms do or do not adjust their price. Therefore, aggregate supply is either perfectly price elastic or perfectly inelastic.

I shall show that these results, as well as the size of menu costs required for price level stickiness, depend heavily upon the way in which the labor market is modelled. My starting point is a suitably modified version of the BLANCHARD and KIYOTAKI [1987] model. Given a one percent increase of money supply, a fraction p of firms adjusts their prices optimally while other firms keep their prices fixed. I compute the profits lost by these firms in percent of revenue. I then consider fixed wages, wages set on a monopolistically competitive market, market clearing wages, and efficiency wages. The computed loss of profits defines the size of menu costs required to establish the model's outcome as a Nash equilibrium.

The results may be summarized as follows. (1) With market clearing wages and identical preferences of househoulds, the loss of profits of non-maximizers is independent of whether wages are set monopolistically or competitively. Yet, losses depend crucially upon the elasticity of labor supply with respect to the real wage and the elasticity of substitution between any two of the produced goods, which determines the degree of competitiveness of the product market. For empirically plausible values of both elasticities, the menu costs required to imply a certain degree of price level stickiness seem unrealistically high. (2) Moreover, there is a range of values of both elasticities such that more than one Nash equilibrium exists. In these cases prices and, hence, menu costs are not uniquely determined. (3) When firms set wages in order to control labor productivity, the sensitivity of work effort with respect to the real wage has no significant effect upon profits lost by non-maximizers. Thus, the size of menu costs required for fixed prices is much more plausible. (4) Fixed wages and efficiency wages imply strategic complementarity. Unless menu costs are above the level that would prevent all firms from adjusting their prices, in a stable Nash equilibrium either all firms do or do not adjust prices. With flexible wages, profits lost may decrease with the fraction of maximizing firms and strategic substitutability arises. The stable equilibrium is the one in which a fraction of firms does not adjust their prices. The elasticity of real GNP with respect to nominal GNP ranges in between zero and one and declines with the size of the demand shock.

The next section provides an intuitive explanation for these results. They are based on a general equilibrium model set up in section 3. Section 4 analyzes equilibria with a fraction of non-maximizers. It reports the loss of profits incurred by non-maximizing firms for a variety of parameter constellations. Section 5 offers concluding remarks. The Appendix covers technical details.

2. Profits Lost by Non-Maximizing Firms

Consider the price decision of a monopolistically competitive firm.[1] The solution to this textbook problem is depicted in figure 1. Faced with demand D_0 and

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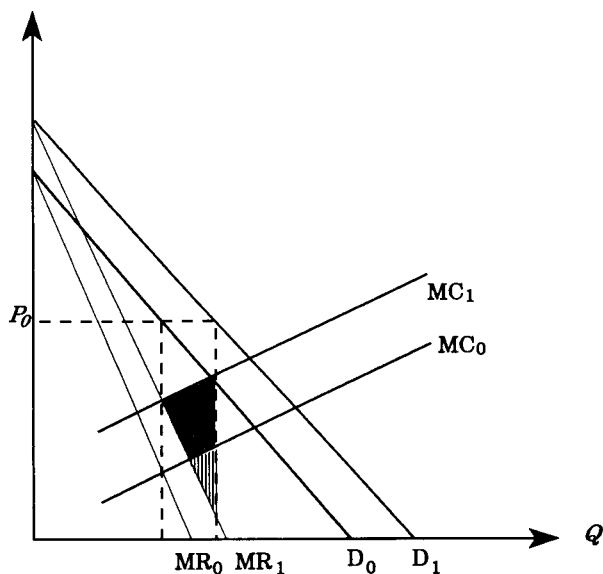[1] I am grateful to the referee who suggested the following exposition.

Figure 1

marginal costs MC_0 its optimal price is P_0. Let the demand function shift to position D_1. The firm maintains its price and produces beyond the point where marginal costs equal marginal revenue. It incurs a loss of profits measured by the area of the hatched triangle. I shall label this the demand-pull effect. In a general equilibrium framework with a money supply shock, the shift of the firm's demand function depends upon the size of the shock and upon the price decisions of its competitors. The more of them decide to adjust their price, the further D_1 is to the right of D_0. Thus, the demand-pull effect is positively related to the fraction of price-adjusting firms.

If marginal costs shift upwards in response to the shock, which cannot happen in the yeoman farmer model of BALL and ROMER [1990], the firm suffers from an additional loss measured by the area of the shaded trapezoid. It depends upon the modelling of the labor market whether this cost-push effect unambiguously increases with the fraction of price-adjusting firms.

In the efficiency wage model of AKERLOF and YELLEN [1985], labor productivity increases with the real wage. If other firms raise their prices the real wage of workers at firms with fixed wages decreases. Labor productivity declines and marginal costs increase. Thus, the cost-push effect is positively related to the fraction of price-adjusting firms.

Consider instead market clearing wages and a one precent increase in the money supply. At constant prices, output must rise by one percent. If labor supply is sufficiently inelastic, nominal wages must rise by more than one

percent. On the other hand, if all firms adjust prices, output remains constant and nominal wages increase by one percent. Under these circumstances, the cost-push effect declines with the fraction of price-adjusting firms.

3. The Model

I consider an economy with a continuum of firms and households of equal size, indexed on the unit interval by j and h respectively.[2] Each firm produces a single good Y_j using the labor services N_h of all households. Households own the economy's given stock of money, M, receive wages and dividends and consume the production of firms.

3.1 Households

The utility of household h is a function of its consumption bundle $\{C_{hj}\}_{j=0}^1$, its holdings of real cash balances, M_h/P, and its labor supply N_h. The specific functional form is:

(1)
$$\gamma C_h^\theta (M_h/P)^{(1-\theta)} - \frac{\varepsilon-1}{\varepsilon\beta} N_h^\beta, \qquad C_h := \left\{ \int_0^1 C_{hj}^{(\varepsilon-1)/\varepsilon} \, dj \right\}^{\varepsilon/(\varepsilon-1)},$$

$$\gamma := \theta^{-\theta}(1-\theta)^{(\theta-1)}, \quad \theta \in (0,1), \quad \varepsilon > 1, \quad \beta \geq 1.$$

The parameter γ normalizes the marginal utility of real income to one. In the case of competitive wage and price setting (or equal mark-ups on both markets), the term $(\varepsilon-1)/(\varepsilon\beta)$ secures a real wage of equal to one. ε and β are the focal parameters of this paper. ε is the elasticity of substitution between any two consumption goods. The case $\varepsilon \to \infty$ reflects a perfectly competitive product market. $1/(\beta-1)$ is the elasticity of labor supply with respect to real wages. θ determines the fraction of the household's budget spent on consumption goods. This parameter has no influence upon profits lost by non-maximizers.

The household's budget constraint,

(2)
$$\int_0^1 P_j C_{hj} \, dj + M_h \leq W_h N_h + D_h + \bar{M}_h,$$

---

[2] This is just for convenience. Nothing essential would change if I used [0, J] and [0, H] instead of [0, 1]. The original version of BLANCHARD and KIYOTAKI [1987] considers a countable set of firms and households. This has the disadvantage that the function relating the loss of profits of non-maximizers to the fraction of maximizing firms is defined only on the set of non negative rational numbers. With a continuum of firms, this function is defined on the interval [0, 1].

states that expenditures on consumption goods, $\int_0^1 P_j C_{hj}\, dj$, together with end-of-period cash balances, M_h, must not exceed wage income, $W_h N_h$, dividends received, D_h, and beginning-of-period money holdings $\bar{M}_h$. P_j and W_h denote the price of good j, and the wage of labor service of type h, respectively. In the case of a competitive labor market, household h regards the wage as a parameter of its decision problem. If the labor market is monopolistically competitive, it sets the wage conditional on the labor demand function. In any case, since utility is additively separable in $(C_h, M_h/P)$ and N_h, consumption and money demand are independent of the labor supply decision. Thus, for an arbitrarily given budget B_h, the household's demand for good j is

$$
(3\,\text{a}) \qquad\qquad C_{hj} = \left(\frac{P_j}{P}\right)^{-\varepsilon} \theta \frac{B_h}{P},
$$

and its money demand is

$$
(3\,\text{b}) \qquad\qquad M_h = (1 - \theta) B_h,
$$

with the price level defined by

$$
(4) \qquad\qquad P = \left\{ \int_0^1 P_j^{\,1-\varepsilon}\, dj \right\}^{\frac{1}{1-\varepsilon}}.
$$

Substitution of equations (3) into equation (1) yields utility as a function of the household's real budget B_h/P and its labor supply N_h:

$$
(5) \qquad\qquad V_h = \frac{B_h}{P} - \frac{\varepsilon - 1}{\varepsilon \beta} N_h^\beta.
$$

Equation (3 a) implies the market demand for good j:

$$
(6) \qquad\qquad C_j = \left(\frac{P_j}{P}\right)^{-\varepsilon} \theta \frac{B}{P}, \quad B := \int_0^1 B_h\, dh.
$$

3.2 Firms

The production function of firm j relates its output Y_j to the inputs of the different types of labor services N_{jh} according to

$$
(7) \qquad Y_j = \frac{\sigma}{\alpha(\sigma - 1)} \left\{ \int_0^1 N_{jh}^{(\sigma-1)/\sigma}\, dh \right\}^{\frac{\alpha\sigma}{\sigma-1}}, \quad \sigma > 1, \quad \alpha \in (0, 1].
$$

The elasticity of substitution between any two different types of labor services is σ. Labor is homogeneous if $\sigma \to \infty$. α is the elasticity of production with

respect to total labor input as defined by the index formula

$$N_j := \left\{ \int_0^1 N_{jh}^{(\sigma - 1)/\sigma} \, dh \right\}^{\frac{\sigma}{\sigma - 1}} .$$

The term $\dfrac{\sigma}{\alpha(\sigma - 1)}$ combined with the corresponding term of the household's utility function normalizes the equilibrium real wage. Cost minimization, min $K_j := \int_0^1 W_h N_{jh} \, dh$ subject to equation (7), determines the demand for labor services of type h by firm j:

$$(8) \qquad\qquad N_{jh} = \left(\frac{W_h}{W} \right)^{-\sigma} \left(\frac{\alpha(\sigma - 1)}{\sigma} Y_j \right)^{1/\alpha}$$

and implies the cost function

$$(9) \qquad\qquad K_j = \left(\frac{\alpha(\sigma - 1)}{\sigma} Y_j \right)^{1/\alpha} W,$$

where aggregate wages W are given by

$$(10) \qquad\qquad W := \left\{ \int_0^1 W_h^{1 - \sigma} \, dh \right\}^{\frac{1}{1 - \sigma}} .$$

The demand for labor services of type h is the sum of equation (8) over all firms:

$$(11) \qquad\qquad N_h^d = \left(\frac{W_h}{W} \right)^{-\sigma} \int_0^1 \left(\frac{\alpha(\sigma - 1)}{\sigma} Y_j \right)^{1/\alpha} dj .$$

3.3 Prices and Wages

The product price of firm j maximizes profits, $P_j Y_j - K_j$, subject to the demand function (6). The solution is:

$$(12\,a) \qquad\qquad P_j = \frac{\varepsilon}{\varepsilon - 1} W \frac{\sigma - 1}{\sigma} \left(\frac{\alpha(\sigma - 1)}{\sigma} Y_j \right)^{\frac{1 - \alpha}{\alpha}} .$$

The firm calculates its price via a constant mark-up $1/(\varepsilon - 1)$ on marginal costs. At this price, the firm produces as much as consumers demand:

$$(12\,b) \qquad\qquad Y_j = C_j .$$

If the labor services of different households are imperfect substitutes for each other, the wage set by household h maximizes the utility function (5) subject to

the labor demand function (11). The wage is chosen via a constant mark-up $1/(\sigma - 1)$ on the marginal disutility of labor:

$$(13\,a) \qquad \frac{W_h}{P} = \frac{\sigma}{\sigma - 1} \frac{\varepsilon - 1}{\varepsilon} N_h^{\beta - 1} .$$

At this wage, the household supplies as much labor as producers demand:

$$(13\,b) \qquad N_h^s = N_h^d .$$

3.4 General Equilibrium

Firms do not differ from one another with respect to their production function and households share the same preferences. The distribution of wealth among households is without significance because of the separability properties of the utility function. Therefore, in general equilibrium, all firms set the same price and all households choose the same wage: $P = P_j \; \forall j \in [0, 1]$ and $W = W_h$ $\forall h \in [0, 1]$. From equation (6), demand for good j is $\theta B/P$, and all firms must produce the same amount, $Y = Y_j \; \forall J \in [0, 1]$. Likewise, equation (13 a) implies that all households supply the same quantity of labor services, $N = N_h \forall h \in [0, 1]$. Since the budget of all households must be

$$B: = \int_0^1 P_j Y_j + M, \quad M: = \int_0^1 M_h ,$$

equation (6) and equation (12 b) determine the market clearing level of production:

$$(14) \qquad Y_j = \frac{\theta}{1 - \theta} \frac{M}{P} .$$

Eliminating Y_j from equation (12 a) by using equation (11), $W = W_h$, and $Y = Y_j$ yields the aggregate demand for labor services for type h, N_h, as a function of the real wage. This function and equations (13) imply the equilibrium real wage:

$$(15\,a) \qquad \omega^* := \frac{W_h}{P} = \frac{W_h}{P_j} = \frac{W}{P} = \frac{\varepsilon - 1}{\varepsilon} \frac{\sigma}{\sigma - 1} .$$

Perfect competition in both the product and the labor market, i.e. $\varepsilon, \sigma \to \infty$, would yield a real wage equal to one. Heterogenous products and homogenous labor services would imply a real wage of less than one. Thus, the real wage is the smaller, the more competitive the labor market is compared to the product

market. The equilibrium real wage and equations (13) determine labor supply and demand:

$$(15\,\text{b}) \qquad\qquad N_j^* = N_h^* = 1 \,.$$

Therefore, from equation (7), production of firm j is

$$(15\,\text{c}) \qquad\qquad Y_j^* = \frac{\sigma}{\alpha(\sigma - 1)} \,.$$

Equation (15c) and equation (14) determine the equilibrium price level,

$$(15\,\text{d}) \qquad\qquad P^* = P_j^* = \frac{\alpha(\sigma - 1)}{\sigma}\,\frac{\theta}{1 - \theta}\,M \,,$$

which is directly proportional to money supply.

3.5 Efficiency Wages

Suppose, for convenience, that labor services are homogenous and aggregate labor supply exceeds aggregate labor demand in the range of real wages considered below. The production of firm $j \in [0, 1]$ depends on labor services measured in efficiency units, $e_j N_j$, according to

$$(16) \qquad\qquad Y_j = \frac{1}{\alpha}\left(e_j N_j\right)^{\alpha}, \quad \alpha \in (0, 1] \,.$$

AKERLOF and YELLEN [1985] assume that the efficiency factor of one unit of physical labor input, e_j, is the following function of the workers' real wage:

$$(17) \qquad\qquad e_j = -a + b\left(\frac{W_j}{P}\right)^{\xi}, \quad \xi \in (0, 1), \quad a, b > 0 \,.$$

W_j is the wage paid by firm j, and P is the price level defined by equation (4). Firm j's price P_j and wage offer W_j maximize profits subject to (17) and the demand function (6). A symmetric equilibrium determines prices and quantities as functions of the model's parameters. The solutions are:

$$(18\,\text{a}) \qquad\qquad \omega^* := \frac{W}{P} = \frac{W_j}{P_j} = \left(\frac{a}{b(1 - \xi)}\right)^{1/\xi},$$

$$(18\,\text{b}) \qquad\qquad e_j =: e^* = a\,\frac{\xi}{1 - \xi},$$

(18c)
$$N_j^* = \frac{1}{e^*} \left(\frac{\varepsilon}{\varepsilon - 1} \frac{\omega^*}{e^*} \right)^{\frac{1}{\alpha - 1}},$$

(18d)
$$Y_j^* = \frac{1}{\alpha} \left(\frac{\varepsilon}{\varepsilon - 1} \frac{\omega^*}{e^*} \right)^{\frac{\alpha}{\alpha - 1}},$$

(18e)
$$P_j^* = P^* = \frac{\theta}{1 - \theta} M \left(\frac{\varepsilon}{\varepsilon - 1} \frac{\omega^*}{e^*} \right)^{\frac{\alpha}{1 - \alpha}}.$$

Therefore, as in the model before, the price level is unit elastic with respect to money supply.

4. Equilibria With Maximizing and Non-Maximizing Firms

Suppose a lump sum transfer to households increases the stock of money from M_0 to $M_1 = (1 + m) M_0$, by $m \times 100$ percent. At given prices and wages, aggregate demand rises by $m \times 100$ percent. As a response, a fraction ρ of firms adjusts their prices optimally taking into account the behavior of $1 - \rho$ firms that do not change their prices but expand production appropriately. The insight of the early menu costs literature is that, according to the envelope theorem, the difference between the profits of price-adjusting firms (henceforth labeled maximizers) and the profits of firms with fixed prices (the non-maximizers) is of second order (with respect to a Taylor's series expansion of the profit function). But how large is this second order effect, e.g., in percent of revenue? Thus, what is the size of fixed costs of price adjustment (menu costs) necessary to make $1 - \rho$ firms indifferent between the option of raising their price and paying the menu costs and that of maintaining their price and saving the menu costs? This section provides an answer that depends crucially upon the behavior of wages.

4.1 Fixed Wages

Let $P_i, i \in [0, \rho]$, denote the price of maximizing firms and $P_k = P^*$, $k \in (\rho; 1]$ the price of non-maximizing firms. With a fraction ρ of maximizing firms, the price level implied by definition (4) is:

(19)
$$P = \left\{ \rho P_i^{1 - \varepsilon} + (1 - \rho) P_k^{1 - \varepsilon} \right\}^{\frac{1}{1 - \varepsilon}},$$

and nominal GNP is:

(20)
$$P Y = \int_0^\rho P_i Y_i \, di + \int_\rho^1 P_k Y_k \, dk = \rho P_i Y_i + (1 - \rho) P_k Y_k.$$

At prices P_i and P_k, respectively, both maximizers and non-maximizers produce as much as consumers demand. Thus, Y_i and Y_k must solve the two linear equations:

(21)
$$Y_i = \left(\frac{P_i}{P}\right)^{-\varepsilon} \theta \frac{P Y + M}{P},$$

$$Y_k = \left(\frac{P_k}{P}\right)^{-\varepsilon} \theta \frac{P Y + M}{P}.$$

It is easily verified that

$$(22) \qquad Y_j = \left(\frac{P_j}{P}\right)^{-\varepsilon} \frac{\theta}{1 - \theta} \frac{M}{P}, \quad j = i, k,$$

solves this system. Substituting Y_i in equation (12a) by the right hand side of equation (22) for $j = 1$ yields

$$(23) \qquad P_i = \left(\frac{\varepsilon}{\varepsilon - 1} \frac{\sigma - 1}{\sigma} W\right)^{\alpha\pi} \left(\frac{\alpha(\sigma - 1)}{\sigma} \frac{\theta}{1 - \theta} M_1\right)^{(1 - \alpha)\pi} P^{(\varepsilon - 1)(1 - \alpha)\pi},$$

$$\pi := \frac{1}{\alpha + \varepsilon(1 - \alpha)}.$$

This equation implicitly defines the profit maximizing price P_i as a function of wages, money supply and the fraction of maximizers. It reflects the demand-pull effect: it is increased demand that motivates firms faced with diminishing returns to scale to raise their prices. If marginal costs are constant, i.e. $\alpha = 1$, the profit-maximizing price is independent of the level of demand, and equation (23) implies $P_i = P_k = P^*$.

Equation (23) has a unique solution in P_i for given values of W, m, ρ, and the model's parameters (see Appendix A). Taylor's theorem permits an approximate solution:

$$(24) \qquad P_i \simeq P_k + \frac{1 - \alpha}{\alpha + \varepsilon(1 - \alpha) - \rho(\varepsilon - 1)(1 - \alpha)} P_k m.$$

Apply Taylor's theorem to the profit function

$$\Pi(P_k) := \left(\frac{P_k}{P}\right)^{1 - \varepsilon} \theta B - W \left[\frac{\alpha(\sigma - 1)}{\sigma} \left(\frac{P_k}{P}\right)^{-\varepsilon} \theta \frac{B}{P}\right]^{1/\alpha},$$

to get

$$\Delta\Pi := \Pi(P_k) - \Pi(P_i) \simeq \Pi'(P_i)(P_k - P_i) + \tfrac{1}{2}\Pi''(P_i)(P_k - P_i)^2$$

$$= -\frac{1}{2} P_i Y_i \frac{\varepsilon - 1}{\alpha\pi} (P_k - P_i)^2,$$

where $\Pi'(P_i)$ and $\Pi''(P_i)$ denote the first and second derivative of the profit function evaluated at P_i. Note that $P_i = P_k$ at $m = 0$ and, hence, $\Pi'(P_i) = 0$. Eliminate $(P_k - P_i)^2$ using (24) and divide by $P_i Y_i = P_k Y_k$. The ensuing formula

$$(25) \qquad \frac{\Delta \Pi}{P_k Y_k} \simeq -\frac{1}{2} \frac{\varepsilon - 1}{\alpha \pi} \left[\frac{1 - \alpha}{(\alpha + \varepsilon(1 - \alpha) - \rho(\varepsilon - 1)(1 - \alpha)} \right]^2 m^2$$

approximates the loss of profits in percent of revenue incurred by non-maximizers. This loss is a function of $\alpha, \varepsilon, \rho$ and m. Formula (25) (and more general Appendix A) proves that the demand-pull effect is an increasing function of the fraction of maximizers ρ. The underlying economic reasoning is this: the price level increases with ρ. Firms keeping their nominal prices fixed experience decreasing relative prices. Consequently, they produce the further beyond the point at which marginal revenue covers marginal costs, the more other firms decide to adjust prices.

Table 1 reports the results of numerical examples. For a one percent increase in money supply it displays the loss of profits in percent of (orginal) revenue and, in parentheses, the associated percentage increase of aggregate employment. $\rho = 0 (\rho = 1)$ marks the case where all firms but one keep their prices fixed (adjust prices). The figures are derived from solutions of equation (23). Especially for high values of ε, there is a significant difference between results derived from the approximate formula (25) and those based on solutions of equation (23). The values of parameters with no obvious influence, namely θ, σ, and β, were chosen for convenience.

The loss of profits declines with the elasticity of production with respect to total labor input, α, and rises with the elasticity of substitution with respect to any two of the consumer goods. Labor's share in GNP, which is not smaller than 0.65, provides a proxy of α. Empirically plausible mark-ups[3] favor $\varepsilon = 7.7$. The respective entries of table 1 are quite small, 0.008 ($\alpha = 0.75, \varepsilon = 7.7$) percent of revenue being the biggest. Even in a highly competitive product market, $\varepsilon = 20.1$, the loss is less than 0.15 percent. These results, so far, confirm the argument that even small menu costs might suffice to prevent price adjustment.

4.2 Flexible Wages

Suppose wages respond to increased labor demand. Then, wages satisfy equation (13a) in the case of a monopolistically competitive labor market. If the labor market is perfectly competitive, wages satisfy equation (13a) with the term $\dfrac{\sigma}{\sigma - 1}$ replaced by 1. Again, symmetry implies $W_h = W \; \forall \, h \in [0, 1]$. Hence,

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[3] See, e.g., HALL [1988] and SCHERER [1980].

Table 1

α	ρ	ε	ε	ε	ε
		2.0	5.0	7.7	20.1
0.25	0.00	0.006	0.011	0.013	0.014
		(4.06)	(4.06)	(4.06)	(4.06)
	0.25	0.008	0.017	0.020	0.024
		(3.58)	(3.84)	(3.92)	(4.01)
	0.50	0.011	0.029	0.037	0.050
		(2.96)	(3.48)	(3.67)	(3.92)
	0.75	0.014	0.060	0.92	0.161
		(2.14)	(2.80)	(3.12)	(3.69)
	1.00	0.020	0.191	0.499	4.253
		(1.00)	(1.00)	(1.00)	(1.00)
0.500	0.00	0.002	0.003	0.004	0.005
		(2.01)	(2.01)	(2.01)	(2.01)
	0.25	0.002	0.005	0.006	0.008
		(1.83)	(1.91)	(1.94)	(1.98)
	0.50	0.002	0.008	0.010	0.015
		(1.61)	(1.76)	(1.83)	(1.93)
	0.75	0.003	0.013	0.022	0.044
		(1.34)	(1.51)	(1.61)	(1.81)
	1.00	0.004	0.031	0.076	0.556
		(1.00)	(1.00)	(1.00)	(1.00)
0.650	0.00	0.001	0.002	0.002	0.002
		(1.54)	(1.54)	(1.54)	(1.54)
	0.25	0.001	0.002	0.003	0.004
		(1.44)	(1.48)	(1.49)	(1.52)
	0.50	0.001	0.003	0.004	0.007
		(1.31)	(1.38)	(1.42)	(1.48)
	0.75	0.001	0.005	0.008	0.019
		(1.17)	(1.24)	(1.29)	(1.40)
	1.00	0.001	0.009	0.022	0.147
		(1.00)	(1.00)	(1.00)	(1.00)
0.75	0.00	0.000	0.001	0.001	0.001
		(1.34)	(1.34)	(1.34)	(1.34)
	0.25	0.000	0.001	0.001	0.002
		(1.27)	(1.29)	(1.30)	(1.32)
	0.50	0.000	0.001	0.002	0.004
		(1.19)	(1.22)	(1.25)	(1.29)
	0.75	0.000	0.002	0.004	0.010
		(1.10)	(1.14)	(1.16)	(1.22)
	1.00	0.001	0.003	0.008	0.048
		(1.00)	(1.00)	(1.00)	(1.00)

$\beta = 7.7; \theta = 0.5; m = 0.01; \sigma = \varepsilon$

demand for labor service of type h is

$$(26) \qquad N_h^d = \rho \left(\frac{\alpha(\sigma - 1)}{\sigma} Y_i \right)^{1/\alpha} + (1 - \rho) \left(\frac{\alpha(\sigma - 1)}{\sigma} Y_k \right)^{1/\alpha} .$$

The first term of the right hand side of equation (26) is the labor demand of maximizing firms, the second term is labor demanded by non-maximizers. Replacing N_h in equation (13a) by the right hand side of equation (26), and substituting for Y_i and Y_k from equations (21), yields W as a function of P_i. This function can be used to eliminate W in equation (23). The ensuing equation, written in implicit form, determines the optimal price of maximizing firms as a function of ρ, m, and the former optimal price $P^* = P_k$:

$$(27) \qquad \psi(P_i) = \left(\frac{\alpha(\sigma - 1)}{\sigma} \frac{\theta}{1 - \theta} M_1 \right)^{(\beta - \alpha)\pi} P^{[\alpha + (\varepsilon - 1)(\beta - 1)]\pi}$$

$$\times \left(\rho P_i^{-\varepsilon/\alpha} + (1 - \rho) P_k^{-\varepsilon/\alpha} \right)^{\alpha(\beta - 1)\pi} - P_i .$$

Appendix B proves that a solution of equation (27) exists. Yet, there may be more than one solution. Figure 1 illustrates this possibility for quite plausible values of the model's parameters. The reason for this ambiguity is the behavior of labor demand, equation (26), with respect to the price of maximizing firms. Consider P_i increasing the interval $[P^*, \infty)$. The relative price of non-maximizers declines steadily, shifting product demand from maximizing to non-maximizing firms. Initially, planned lay-offs at maximizing firms overcompensate planned hiring by non-maximizing firms. The demand for labor services of type h declines. When the maximizers' share of the product market has become small, planned hiring outweighs planned lay-offs, and labor demand rises (see Appendix C). If the elasticity of labor supply with respect to the real wage is small, there may be three equilibria in the labor market. Since the loss of profits of non-maximizers increases with the price difference $P_k - P_i$, menu costs required to establish the equilibrium labeled C in figure 2 are noticeably greater than those necessary to establish equilibrium A.

The results summarized in table 2 are based – if necessary – on the optimal price that is closest to the original price. A variety of numerical experiments confirms the conjecture that profits lost decline with the elasticity of production with respect to labor input, α. The figures in table 2 were calculated with $\alpha = 0.75$. The values of β and ε are essentially those used by BALL and ROMER [1990] and BLANCHARD and KIYOTAKI [1987]. The remaining, inessential parameters were chosen to imply $w^* = 1$ and $N_h^* = 1$. As in table 1, the numbers in parentheses are the percentage increase of employment when money supply rises by one percent and when a fraction $1 - \rho$ of firms keeps their prices fixed.

Table 2 reveals a variety of cases where profits lost are significant in size. If all firms but one increase prices, aggregate production and employment do not
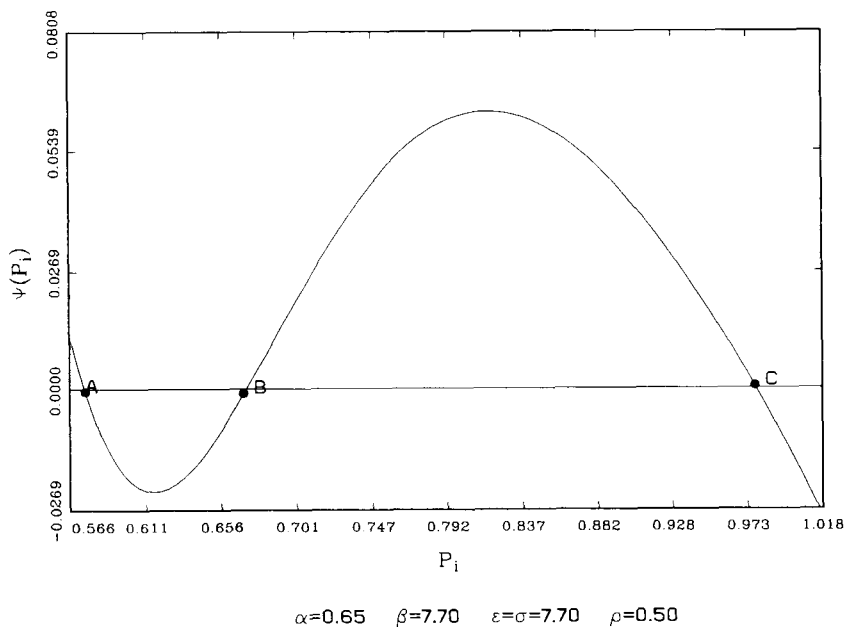
$$\alpha=0.65 \quad \beta=7.70 \quad \varepsilon=\sigma=7.70 \quad \rho=0.50$$

Figure 2

change. The wage of the single non-maximizer increases by one percent and is independent of β. Even in this case and for $\varepsilon = 7.7$, the non-maximizers loss (0.126 percent of revenue) is more than fifteen times larger than with constant wages (0.008 percent of revenue). If the fraction of non-maximizers is greater than zero, their losses increase with β. Empirically, the elasticity of labor supply with respect to the real wage, $1/(\beta - 1)$, is small[4], implying a β not smaller than 7.7. Combined with $\varepsilon = 7.7$, in two out of five cases profits lost are bigger than 0.5 percent of revenue. Menu costs of about 0.5 percent of revenue, however, seem unrealistically large.

Since the wage increase is independent of σ, the figures of table 2 would not change if a perfectly competitive labor market were assumed rather than a monopolistically competitive labor market.

Table 2 shows that there is no monoton relation between profits lost and the fraction of maximizers. The underlying logic is that the market clearing wage may decline with the fraction of maximizers. To see this, consider the polar cases $\rho = 0$ and $\rho = 1$. In the first case the price level does not change and production rises by one percent, requiring nominal wages to rise by $(\beta - 1)/\alpha$ percent. If $\rho = 1$, prices and wages rise by one percent. Thus, if β is greater than $1 + \alpha$, the wage increase for small ρ exceeds one percent and must decrease as ρ approach-

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[4] See, e.g., KILLINGSWORTH [1983].

Table 2

α	ρ	ε	ε	ε	ε
		2.0	5.0	7.7	20.1
1.2	0.00	0.001	0.003	0.003	0.004
		(1.34)	(1.34)	(1.34)	(1.34)
	0.25	0.002	0.004	0.005	0.008
		(1.19)	(1.24)	(1.27)	(1.30)
	0.50	0.002	0.007	0.010	0.0150
		(0.98)	(1.09)	(1.15)	(1.24)
	0.75	0.004	0.016	0.024	0.047
		(0.64)	(0.80)	(0.90)	(1.10)
	1.00	0.008	0.055	0.126	0.858
		(0.00)	(0.00)	(0.00)	(0.00)
2.0	0.00	0.008	0.021	0.026	0.034
		(1.34)	(1.34)	(1.34)	(1.34)
	0.25	0.008	0.026	0.035	0.054
		(1.00)	(1.11)	(1.17)	(1.26)
	0.50	0.008	0.032	0.050	0.097
		(0.67)	(0.83)	(0.93)	(1.13)
	0.75	0.008	0.042	0.076	0.221
		(0.34)	(0.47)	(0.57)	(0.86)
	1.00	0.008	0.055	0.126	0.858
		(0.00)	(0.00)	(0.00)	(0.00)
7.7	0.00	0.261	0.635	0.786	1.020
		(1.34)	(1.34)	(1.34)	(1.34)
	0.25	0.060	0.288	0.519	1.561
		(0.48)	(0.67)	(0.81)	(1.26)
	0.50	0.025	0.146	0.310	2.154
		(0.21)	(0.32)	(0.42)	(1.00)
	0.75	0.014	0.085	0.191	1.498
		(0.08)	(0.12)	(0.16)	(0.42)
	1.00	0.008	0.055	0.126	0.858
		(0.00)	(0.00)	(0.00)	(0.00)
20.1	0.00	2.074	4.825	5.867	7.399
		(1.34)	(1.34)	(1.34)	(1.34)
	0.25	0.104	0.726	2.138	698.6
		(0.23)	(0.39)	(0.60)	(11.32)
	0.50	0.031	0.210	0.532	1.986E + 04
		(0.08)	(0.14)	(0.20)	(27.67)
	0.75	0.015	0.097	0.229	4.326E + 06
		(0.03)	(0.05)	(0.06)	(60.86)
	1.00	0.008	0.055	0.126	0.858
		(0.00)	(0.00)	(0.00)	(0.00)

$\alpha = 0.75; \theta = 0.5; m = 0.01; \sigma = \varepsilon$

es one. In that case the cost-push effect opposes the demand-pull effect and may dominate or come to dominate the latter (see figure 3, Panel (b) and Panel (c), respectively). Only if the demand-pull effect is strong enough from the beginning, do profits lost steadily increase with the fraction of firms adjusting prices (see figure 3, Panel (a)).

Consider the case shown in Panel (a) of figure 3. Suppose there are costs of adjusting prices of size *mc*. At point B, each firm is indifferent between the option of keeping its price fixed and saving the menu costs and the alternative of raising its price and paying the menu costs. Yet, since the losses of non-maximizers increase with the fraction of maximizers, the Nash equilibrium at B is unstable. A small increase of ρ raises profits lost above the menu costs and triggers a positive feed-back effect that finally induces all firms to raise prices. Likewise, a small decrease of ρ causes all firms to keep their prices fixed. Within a range of money supply shocks where menu costs are smaller than profits lost at $\rho = 1$, the aggregate supply function is either perfectly price elastic or perfectly inelastic. The interdependence between the decision of one fraction of firms to change its price and the decision of other firms to change their price is an example of strategic complementarity in the sense defined by COOPER and JOHN [1988].

Stable Nash equilibria require a negative feed-back effect, i.e., strategic substitutability. This occurs if the cost-push effect outweighs the demand-pull effect.

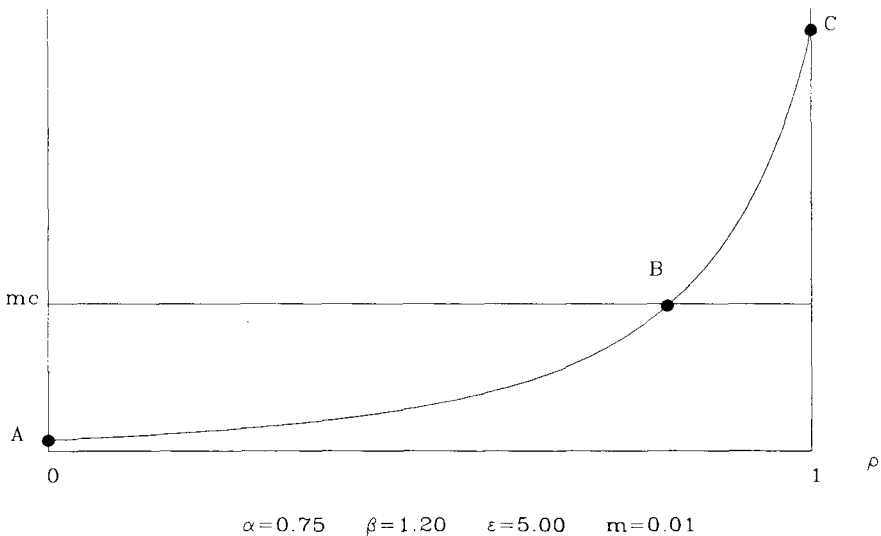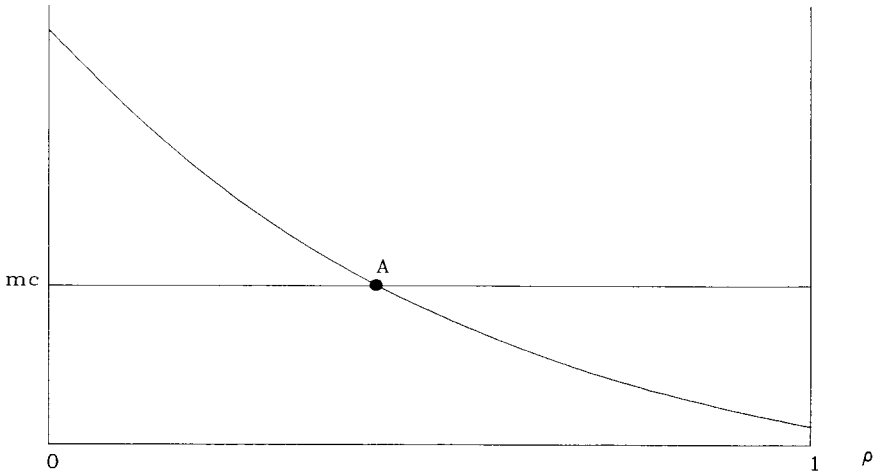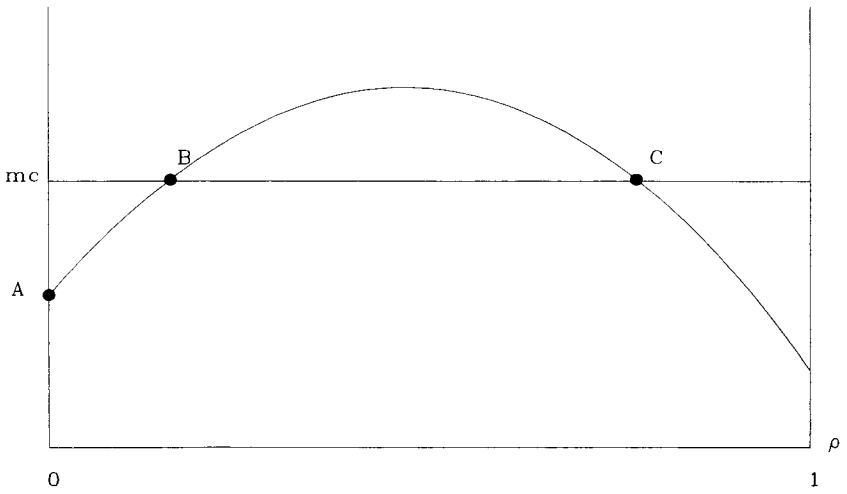$(\Delta \Pi_j / P_j Y_j) * 100$

$\alpha = 0.75 \qquad \beta = 1.20 \qquad \varepsilon = 5.00 \qquad m = 0.01$

Figure 3 a

$(\Delta \Pi_j / P_j Y_j) * 100$

$$\alpha = 0.75 \qquad \beta = 5.00 \qquad \varepsilon = 5.00 \qquad m = 0.01$$

Figure 3 b

$(\Delta \Pi_j / P_j Y_j) * 100$

$$\alpha = 0.75 \qquad \beta = 2.80 \qquad \varepsilon = 5.00 \qquad m = 0.01$$

Figure 3 c

In Panel (b) of figure 3 there is only one equilibrium, the point labeled B. At A, profits lost if all but one firm maintain their prices exceed the menu costs *mc*. At C menu costs are greater than profits lost if all but one firm raise prices. The Nash equilibrium B is stable. A small decrease of ρ raises profits lost above menu costs and other firms find it profitable to adjust prices, offsetting the initial decrease of ρ. Profits lost increase with the size of the money supply shock. The curve ABC in Panel (b) shifts upward if *m* rises. Thus, for given costs of price adjustment, the fraction of price adjusting firms increases with the size of the money supply shock. The aggregate supply function exhibits a decreasing price elasticity.

The intermediate case of Panel (c) shows two stable Nash equilibria: points labeled A and C. Either none or a large fraction of firms adjust prices. B is an unstable equilibrium. D is not an equilibrium, at all.

4.3 Efficiency Wages

Table 3 displays the results of numerical examples of the efficiency wage model. Appendix D covers the technical details of this model. There is a unique optimal price P_i for each fraction of maximizers, and hence no ambiguity with respect to profits lost. The formula approximating profits lost in percent of (original) revenue,

$$
(28) \quad \frac{\Delta \Pi}{P_j Y_j} \simeq -\frac{1}{2} \left[\frac{(\varepsilon - 1)(\alpha + \varepsilon(1 - \alpha))}{\alpha} + \frac{\alpha(\varepsilon - 1)(1 - \xi)}{\varepsilon} \rho^2 \right]
$$
$$
\times \left[\frac{1 - \alpha}{\alpha + \varepsilon(1 - \alpha) - \rho[\alpha + (\varepsilon - 1)(1 - \alpha)]} \right]^2 m^2 ,
$$

indicates that the parameters of the effort function (17) have no influence on profits lost. A variety of numerical experiments confirms this conjecture. They also show that the negative impact of ξ is quite small. This admits setting a, b, and ξ to imply an equilibrium real wage and an equilibrium effort level of one.

Formula (28) is equivalent to formula (25) if $\rho = 0$. In this case the price level does not change and maximizing firms are not forced to offer higher wages that would prevent the effort level from falling. Consequently, the efficiency model is equivalent to the constant wage model if no firm but one adjusts its price.

Table 3 reveals that the efficiency wage model implies noticeably smaller losses than the market clearing wage model. The largest number occurring for $\alpha = 0.75$ is about 0.9 percent of revenue ($\rho = 1$ and $\varepsilon = 20.1$). If the product market is less competitive, e.g. $\varepsilon = 7.7$, it is only for ρ close to one that losses exceed one tenth of a percent.

Table 3 provides evidence of the fact that profits lost increase with the fraction of maximizers. As in the fixed wage model, this can be shown to hold independent of the parameter values chosen. Hence, strategic complementarity exits,

Table 3

α	ρ	ε	ε	ε	ε
		2.0	5.0	7.7	20.1
0.50	0.00	0.002	0.003	0.004	0.005
		(2.01)	(2.01)	(2.01)	(2.01)
	0.25	0.002	0.005	0.006	0.008
		(1.89)	(1.95)	(1.97)	(1.99)
	0.50	0.004	0.010	0.012	0.017
		(1.64)	(1.80)	(1.86)	(1.95)
	0.75	0.007	0.024	0.034	0.056
		(1.14)	(1.44)	(1.58)	(1.82)
	1.00	0.016	0.127	0.315	2.463
		(0.00)	(0.00)	(0.00)	(0.00)
0.75	0.00	0.000	0.001	0.001	0.001
		(1.34)	(1.34)	(1.34)	(1.34)
	0.25	0.001	0.001	0.002	0.002
		(1.30)	(1.31)	(1.32)	(1.33)
	0.50	0.001	0.003	0.004	0.005
		(1.20)	(1.24)	(1.27)	(1.30)
	0.75	0.002	0.007	0.010	0.017
		(0.93)	(1.04)	(1.10)	(1.22)
	1.00	0.009	0.057	0.128	0.860
		(0.00)	(0.00)	(0.00)	(0.00)

$\theta = 0.5$; $a = 1$; $b = 2$; $\xi = 0.5$; $m = 0.01$

and menu costs of a given size imply that stable equilibria have either none or all firms adjusting prices.

5. Conclusion

Fixed costs of price adjustment can prevent firms from changing prices in response to an aggregate demand shock. This is beyond doubt. But, I believe, the really important question is whether they can explain the observed correlation between real and nominal GNP, which is neither zero nor one. This paper shows that the answer depends critically on the behavior of wages.

Fixed wages as well as efficiency wages imply that profits lost by firms that do not adjust their prices are quite small. In most of the cases studied, menu costs of acceptable size could prevent price adjustment. In both models the strategic interdependence between price adjusting and non-adjusting firms is complementary. Hence, either none or all firms adjust their prices. Any intermediate case is unlikely to be observed.

This does not hold true with wages that are set either monopolistically or at market clearing levels. If labor supply is sufficiently inelastic with respect to the

real wage, strategic substitutability may arise. What will be observed are equilibria in which a fraction of firms adjusts prices while other firms keep their prices fixed. The elasticity of real GNP with respect to nominal GNP takes values in between zero and one and declines with the size of the demand shock. Furthermore, real wages are procyclical, which is in line with empirical evidence.[5] Unfortunately, and especially with a sufficiently competitive product market, menu costs required to imply these results seem unrealistically large. The conclusion is somewhat startling: the empirically relevant outcome requires unrealistically large menu costs.

Zusammenfassung

Ich untersuche die Bedeutung der Lohnbildung für Preisniveaustarrheiten im Rahmen des Menu Costs Ansatzes. Die Nominallöhne sind flexibel und die Zahl der Unternehmen, welche ihre Preise an Nachfrageschocks anpassen, ist variabel. Für empirisch plausible Parameterwerte entsteht strategische Substitutionalität zwischen den Unternehmen. In diesem Fall ist die Preiselastizität der aggregierten Güterangebotsfunktion weder null noch unendlich, allerdings sind mit dieser Situation unrealistisch große Menu Costs verbunden. Bei Effizienzlöhnen und starren Nominallöhnen passen entweder alle Unternehmen die Preise an oder halten sie konstant. In beiden Fällen sind die für starre Preise erforderlichen Menu Costs sehr klein.

Appendix

A) Existence of Solutions of Equation (23)

Let

$$(A\,1) \quad \psi(P_i) := \left(\frac{\varepsilon}{\varepsilon - 1}\frac{\sigma - 1}{\sigma}W\right)^{\alpha\pi}\left(\frac{\alpha(\sigma - 1)}{\sigma}\frac{\theta}{1 - \theta}M_1\right)^{(1 - \alpha)\pi}P^{(\varepsilon - 1)(1 - \alpha)\pi} - P_i,$$

with π defined in (23). This function is continuously differentiable in P_i. It is positively valued at $P_i = P^*$,

$$(A\,2) \qquad \psi(P_i = P^*) = P^*\left[(1 + m)^{(1 - \alpha)\pi} - 1\right] > 0 \text{ for } m > 0,$$

and approaches $-\infty$ as $P_i \to \infty$. Thus, there must be at least one $P_i^* \in (P^*, \infty)$

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[5] More recent empirical papers on this subject are GARMAN and RICHARDS [1992] and SOLON, BARSKY and PARKER [1994].

solving equation (23). At P_i^* the derivative of $\psi(P_i)$ is

$$\psi'(P_i^*) = s - 1 - s\pi < 0,$$

(A 3)

$$s := \rho\left(\frac{P_i}{P}\right)^{1-\varepsilon} = \frac{\int_0^\rho P_i Y_i \, di}{P Y} \in [0, \rho] \quad \text{for } P_i \in [P^*, \infty),$$

where s is the market share of maximizers. Thus, $\psi(P_i)$ cuts the abzissa only once and P_i^* is unique.

B) *Zeros of Function* (27)

It is easily seen that the function defined by equation (27) is positively valued at $P_i = P^*$ and approaches $-\infty$ as $P_i \to \infty$. Hence (27) has at least one root $P_i^* \in (P^*, \infty)$. The derivative of (27) evaluated at P_i^* is

$$\psi'(P_i^*) = \pi\left([\alpha + (\varepsilon - 1)(\beta - \alpha)]s - \varepsilon(\beta - 1)\delta(P_i^*) - (1/\pi)\right),$$

(B 1)

$$\delta(P_i^*) := \frac{(P_i^*)^{-\varepsilon/\alpha}}{\rho(P_i^*)^{-\varepsilon/\alpha} + (1 - \rho)(P^*)^{-\varepsilon/\alpha}} \in \left[1, \frac{(P^*)^{\varepsilon/\alpha}}{1 - \rho}\right] \quad \text{for } P_i^* \in [P^*, \infty).$$

This expression, with s as in (A 3), is assuredly negative if $\beta = 1$ but may be positive if β is large. In this case, there must be at least three roots of $\psi(P_i)$.

C) *Properties of Function* (26)

Substitute Y_i and Y_k in equation (26) by the right hand side of (22). Since the price level defined in equation (19) is also a function of P_i, the result,

$$N_h(P_i) := \left(\rho P_i^{-\varepsilon/\alpha} + (1 - \rho)P_k^{-\varepsilon/\alpha}\right)^{1/\alpha}$$

(C 1)

$$\times \left(\frac{\alpha(\sigma - 1)}{\sigma} \frac{\theta}{1 - \theta} M_0(1 + m)\right)^{1/\alpha} P^{(\varepsilon - 1)/\alpha},$$

portrays market demand for labor of type h as a function of P_i. At $P_i = P^*$,

(C 2) $$N_h(P_i = P^*) = N_h^*(1 + m)^{1/\alpha} > N_h^*.$$

Furthermore,

(C 3) $$\lim_{P_i \to \infty} N_h(P_i) = (1 + m)^{1/\alpha}(1 - \rho)^{(\alpha - 1)/\alpha} N_h^* > N_h(P_i = P^*) > N_h^*.$$

The derivative of (C 1) at $P_i = P^*$ is

(C 4) $$\frac{dN_h(P_i = P^*)}{dP_i} = -\frac{\rho N_h^*}{\alpha P^*}(1 + m)^{1/\alpha} < 0.$$

Thus, when P_i departs from P^* and approaches infinity, labor demand first declines but finally increases beyond $N_h(P_i = P^*)$.

D) Equilibria with Maximizers and Non-Maximizers in the Efficiency Wage Model

The profit maximizing price of firm i is

(D 1) $$P_i = \frac{\varepsilon}{\varepsilon - 1}\frac{W_i^*}{e^*}(e^*N_i)^{1-\alpha},$$

where $W_i^* = w^*P$. The production function implies

$$e^*N_i = (\alpha Y_i)^{1/\alpha},$$

and Y_i is given by (22) for $j = i$. Hence, (D 1), the production function, and equation (22) imply

(D 2) $$\psi(P_i) := \left(\frac{\varepsilon}{\varepsilon - 1}\frac{\omega^*}{e^*}\right)^{\alpha\pi}\left(\frac{\alpha\theta}{1-\theta}M_0(1 + m)\right)^{(1-\alpha)\pi}P^{[\alpha + (\varepsilon - 1)(1 - \alpha)]} - P_i.$$

This function, with π as defined in (23), determines the optimal price of maximizers. At $P_i = P^*$, it is positively valued and approaches $-\infty$ as $P_i \to \infty$. Hence, at least one root $P_i^* \in (P^*, \infty)$ exists. The derivative of (D 2) evaluated at $P_i = P_i^*$ is

(D 3) $$\psi'(P_i = P_i^*) = s - 1 - (1 - \alpha)\pi < 0,$$

with s as defined in (A 4), proving the uniqueness of P_i^*.

Approximately, the difference between the optimal price and the price of non-maximizers as derived from (D 2) is

(D 4) $$P_i - P_k \simeq \frac{1 - \alpha}{[\alpha + \varepsilon(1 - \alpha)] - \rho[\alpha + (\varepsilon - 1)(1 - \alpha)]}P_k m.$$

Since $W_i = w^*P$ the difference between the optimal wage and the wage of non-maximizers is

(D 5) $$W_i - W_k \simeq \frac{\rho(1 - \alpha)}{[\alpha + \varepsilon(1 - \alpha)] - \rho[a + (\varepsilon - 1)(1 - \alpha)]}P_k m.$$

Taylor's theorem and the optimality of the former price $P^* = P_k$ and wage $W^* = W_k$ imply

(D6) $\Delta \Pi \simeq \frac{1}{2}(P_i - P_k, \quad W_i - W_k) \begin{pmatrix} \Pi_{PP} & \Pi_{PW} \\ \Pi_{WP} & \Pi_{WW} \end{pmatrix} \begin{pmatrix} P_i - P_k \\ W_i - W_k \end{pmatrix},$

where

(D7) $$\Pi_{PP} = -\frac{\varepsilon - 1}{\alpha \pi} \frac{Y_j^*}{P_j^*}$$

and

(D8) $$\Pi_{WW} = -\frac{(1 - \xi) N_j^*}{W_j^*}$$

are the second derivative of the profit function with respect to price and wage, respectively, both evaluated at $m = 0$. The mixed second partial derivatives of the profit function can be shown to be zero at $m = 0$. Insert (D7) and (D8) into (D6), consider $\Pi_{PW} = \Pi_{WP} = 0$, and divide by $P_j^* Y_j^*$ in order to get equation (28).

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