

INTERINDUSTRY LINKAGES AND THE ACCUMULATION OF PRICE RIGIDITY: A CROSS-INDUSTRY EVIDENCE*

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New Keynesian economics has attempted to justify nominal price rigidity with the "menu cost hypothesis". However, the nature of the menu cost is vague and has not been investigated. I set up an information search model in which firms face information scarcity to set the state-contingent prices in an input-output system. This paper shows that the cost of price adjustment stems from firms information search in a complex input-output system. The model is also able to explain the differing price stickiness across industries and the observed considerable price stickiness of the final goods. This implies that price rigidity accumulates when individual prices pass through an input-output system. Therefore, the model and empirical evidence support the "cumulation hypothesis" as an explanation for nominal price rigidity.

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1. INTRODUCTION

New Keynesian economics has attempted to justify nominal price rigidity with the "menu cost hypothesis" (Akerlof and Yellen(1985), Mankiw(1985), and Parkin(1986)). They asserted that a small fixed menu cost prevents prices from being adjusted fully to the nominal shock or firm-specific condition. However, the nature of the adjustment cost itself is vague and has not been investigated. This paper shows that the adjustment cost stems from firm's information search in a complex input-output system. Under this framework, the model is also able to explain the differing price stickiness across industries and the observed considerable price stickiness of the finished products.

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An input-output model provides a framework for analyzing cost of price adjustment and nominal price rigidity, as Gordon(1990) suggests. In an input-output model, each industry faces a full set of economy-wide and sectoral shocks because industries are intertwined with input-output relations. In order to set the state-contingent price, each firm must estimate not only its input producer's cost and demand shocks, but also all impacts of indirectly linked industrie's cost and demand shocks on its price. However, due to the lack in information on the shocks and the size of linkages to those industries, and computation capacity, it is impossible for a single firm to estimate the impacts of both directly and indirectly linked industries. Therefore, the lack of information prevents firms from setting the state-contingent prices.

I set up an information search model in which firms face information scarcity to set the state-contingent price. At equilibrium, firms are not completely informed, but choose to be partially informed because it is costly to acquire information. They want to have relatively small amount of information because of drastically decreasing marginal benefit and large marginal cost of information search. As a consequence, firms do not adjust prices to the state-contingent level and price rigidity is generated. The information cost gives a rationale for nominal price fixing. Firms may not want to be continuously informed, but may want to be informed at discrete time interval while fixing nominal prices for the periods. The information cost also justifies the nonsynchronized adjustment of prices that gives the aggregate price level inertia (Ball and Cecchetti(1988) and Ball and Romer(1989)).

This approach yields an interesting implication that the price stickiness of industries increases in the unadjusted portion of impacts of industry-specific shocks linked to the industries. This is because an individual firm cannot estimate the impacts of all the linked industries shocks on its price due to enormous information cost. Therefore, the model implies that the price rigidity accumulates when individual prices pass through a complex input-output system. The empirical test on the U.S. industries confirms that the price stickiness of the industries increases in the degree of the impacts of indirectly linked industries in input markets. Therefore, the model and evidence support the "cumulation hypothesis" as an explanation for nominal price rigidity (Blanchard(1987)).

Section II sets up a model of information search in which firms face the scarcity of information to set the state-contingent price. In section III, the industry price stickiness is estimated using fifty five U.S. industries data. The second step tests the relation between price stickiness of industries and the interindustry linkages, using the industry price rigidity estimates and the interindustry linkage measures calculated from the 81-sector U.S. input-output table. Section IV discusses the estimation results and their implication. Section V includes a concluding remark.

II. A MODEL OF INFORMATION SEARCH

There are n industries in an economy in which each industry has a large number of firms. Each firm belonged to an industry is assumed to have some monopolistic power. A firm of the i -th industry uses its upstream industry's product as an input.¹ Labor input is disregarded for simplicity. We assume its equilibrium relative price in \log^2

$$P_i - P = z_i + a_{i-1, i}(P_{i-1} - P) \quad i=1, 2, \dots, n \quad (1)$$

where P_i is the i -th industry's nominal price, P is the aggregate price level, z_i is the i -th industry's demand(or productivity) shock, and $a_{i-1, i}$ is a direct input coefficient of the i -th industry on the $(i-1)$ th industry. We may derive the price equation (1) in a general equilibrium framework like Ball and Cecchetti(1988). However it is important that firm's price depends on upstream industry's price. The price equation (1) expresses such relation reasonably. We also assume that there are many firms with some monopolistic power in an industry and it is not necessary to distinguish firms in the same industry because a firm is a representative one.

We need to note the assumption that an industry uses only its upstream industry's products. Continuously substituting input prices into (1), we have the reduced form of the equilibrium relative price

$$\begin{aligned} P_i - P &= \sum_{h=1}^{i-1} \left(\prod_{j=h}^{i-1} a_{j, j+1} \right) z_h + z_i \\ &= \sum_{h=1}^i \alpha_{hi} z_h, \alpha_{ii} = 1 \end{aligned} \quad (2)$$

where a_{hi} is an (h, i) th element of a direct input coefficient matrix, and α_{hi} is defined as the linkage coefficient of the h -th and i -th industry, that is,

$$\alpha_{hi} = \prod_{j=h}^{i-1} a_{j, j+1}.$$

We assume that each firm in the i -th industry sets the equilibrium nominal price under no uncertainty and cost of price adjustment as follows;

¹ A block-triangular input-output system is assumed for simplicity. An input-output system is said to be block-triangular if each block is dependent only on its upstream block and the industries in each block are arranged a triangular form.

² Equation (1) follows essentially that of Blanchard and Kiyotaki(1987) and Ball and Romer(1989). Their equations are derived from the general equilibrium framework of an economy consisting of identical, monopolistically competitive worker-firms. Heterogeneity of agents in our model makes it very difficult to algebraically derive the pricing equation from a general equilibrium framework.

$$P_{it}^* = \sum_{h=1}^i \alpha_{hi} z_{ht} + P_t \quad (3)$$

The equilibrium relative price equation (3) shows how much information on the entire economy a single individual firm must collect and process to set the state-contingent price when a firm can not observe the current values of the demand shocks and the size of linkages to the relevant industries.

Suppose that the demand shocks are uncertain and it is costly to collect and process the information on the variables. Each firm changes price every period and sets the price by searching information at the end of time $t-1$. Each firm is assumed to choose the level of information (the number of industry visits) r to minimize the sum of mean squared error of the equilibrium price estimator and information search cost.³

$$L_{it}(r) = E[P_{it}^* - P_{it}]^2 + C_i(r), \quad 0 \leq r \leq i. \quad (4)$$

where

$$P_{it} = E[P_{it}^* | \mathcal{Q}_{it}(r)]. \quad (5)$$

The nominal aggregate demand shock $\{m_t\}_{t=0}^{\infty}$ is assumed to be a random walk. Its variance is $\sigma_m^2 t$. An industry-specific demand shock $\{z_{ht}\}_{t=0}^{\infty}$ is assumed to follow a random walk. Its variance is $\sigma_h^2 t$. Industry-specific shocks are assumed to be independent of each other and average to zero over the many firms. The aggregate price level is assumed to follow the nominal aggregate demand with a time lag:⁴

$$P_t = m_{t-1} \quad (6)$$

The following assumptions are made with regard to information and its search cost.

- 1) It is assumed that the current observations on prices are not known.
- 2) The current observation on the nominal aggregate demand is assumed to be known with a one-period lag and the industry-specific demand shocks are

³ Similar quadratic loss functions have been used in a great deal of macroeconomic literature as an approximation to true objective function (Gray(1978) and Fethke and Policano(1984)). However, this objective function is different from that of other models in that the price adjustment cost is endogenously determined in this model while the cost called menu cost is fixed in other models.

⁴ The aggregate price level is exogenously given in this paper. The assumption on the aggregate price level (6) is an approximation of the average of individual prices. The true price level has lagged aggregate demand shocks and a lagged price level term (Ball and Cecchetti(1988)).

assumed to be known with a one-period lag.

- 3) The linkage coefficients α_{hi} ($h=1, 2, \dots, i-1$), are known.
- 4) Each firm begins to search information from its own and neighboring industries, $i, i-1, \dots$ and so on, because their impact on price is bigger than other industries.
- 5) Information search cost depends the number of industry visits r . It costs c to collect and process the data on an industry-specific demand and its impact.⁵

$$C_i(r) = cr, \quad c > 0, \quad 0 \leq r \leq i \quad (0 = \text{no search}, i = \text{full search}) \quad (7)$$

Therefore, if a firm chooses the level of information r , the information available to each firm in the i -th industry is

$$\Omega_{it}(r) = \left\{ m_s (s \leq t-1), z_{js} (j=1, 2, \dots, i-r, 1 \leq j \leq i, s \leq t-1), \right. \\ \left. z_{hs} (h=i-r+1, \dots, i, 1 \leq h \leq i, s \leq t) \right\} \quad (8)$$

where r is the number of industries the informations of which demand shocks are collected, z_{js} is the j -th industry's demand shock which information is not collected, and z_{hs} is the h -th industry's demand shock which information is collected.

Using (5), (3), (6), and (8), the price set by each firm in the i -th industry is

$$P_{it} = E(P_{it}^* | \Omega_{it}) \\ = \sum_{h=i-r+1}^i \alpha_{hi} z_{ht} + \sum_{j=1}^{i-r} \alpha_{ji} z_{jt-1} + m_{t-1} \quad (9)$$

From (3) and (9), the deviation of the price estimator from the equilibrium price is.

$$P_{it}^* - P_{it} = \sum_{h=i-r+1}^i \alpha_{hi} (z_{ht} - z_{ht}) + \sum_{j=1}^{i-r} \alpha_{ji} (z_{jt} - z_{jt-1}) + (m_{t-1} - m_{t-1}) \\ = \sum_{j=1}^{i-r} \alpha_{ji} (z_{jt} - z_{jt-1}) \quad (10)$$

The mean squared error of the price estimator is

⁵ Public information may not be available because a period is very short in this model. Observed prices do not contain the updated information on the shocks. Therefore each firm has to visit other firms in its own industries to get data on demands. Also it will collect data from government agencies. Each firm also must have its own econometric model and/or input-output model. Probably it needs much more sophisticated models than the current models. We can guess the size of cost for the activities.

$$E(P^*_{it} - P_{it})^2 = E\left[\sum_{j=1}^{i-r} \alpha_{ji}^2 (z_{jt} - z_{j,t-1})^2\right] = \sum_{j=1}^{i-r} \alpha_{ji}^2 \sigma_j^2 \quad (11)$$

Therefore, if a firm chooses the level of information r , firm's loss is

$$L_{it}(r) = \sum_{j=1}^{i-r} \alpha_{ji}^2 \sigma_j^2 + cr \quad (12)$$

Note that the interindustry linkage coefficient α_{ji} diminishes when j ($j=1, 2, \dots, i$) increases. The mean squared error part of the loss (12) is convex to the origin if the variances of the industry-specific shocks are the same while the search cost is linearly increasing in r . We highlight the role of interindustry linkages and assume that the variances are the same.⁶ A graphical analysis shows that the optimal level of information r^* is relatively small because of drastically decreasing marginal benefits and large marginal cost of information search (see Figure).

At equilibrium, a firm collects relatively small amount of information and it is incompletely informed. As a consequence, a firm does not set price at state-contingent level and price rigidity is generated. This rigidity gives a rationale for nominal price fixing when it is costly to get new information. A firm may not be continuously informed, but informed at discrete time interval while fixing nominal price for the time periods (Ball and Cecchetti(1988) and Ball and Romer(1989)).

If the price is set at the fully informed level ($r=i$) in (11), the mean squared error of the price is

$$MSE_i(i) = 0 \quad (13)$$

Therefore, the stickiness of price at equilibrium is measured by

$$MSE_i(r^*) - MSE_i(i) = \sum_{j=1}^{i-r^*} \alpha_{ji}^2 \sigma_j^2 = \sum_{j=1}^{i-r^*} \alpha_{ji}^2 \sigma^2 \quad \text{if } \sigma_j^2 = \sigma^2. \quad (14)$$

According to the above relation, the price stickiness increases in the degree of the impact of industry-specific shocks relevant to the optimal level of information r^* that is relatively small. On the other hand, I may infer that the industries relevant to r^* is the directly linked industries to the i -th industry. The reason is that an industry is familiar with its input producer and it can

⁶ It is very difficult to identify all the economy-wide supply and demand shocks and linkages (Gordon(1990)). The shocks may be the variability of upstream and downstream industry disturbances. The variances of the shocks can be obtained under an assumption that the cost and demand shocks follow random walks or white noises. We assume the equal variances in order to emphasize the interindustry linkages.

easily infer the impact of that industry. However, it is really difficult to estimate the impacts of an input producer's input producers on price (Gordon(1990)). The inference is consistent with the result that the optimal level of information is relatively small. Therefore, it is assumed that the number of searched industries are the same over the industries.

$$r_i^* = r^* \quad i = 1, 2, \dots, n. \quad (15)$$

Using (15), the difference in price stickiness between the i -th and $(i-1)$ th industries in this particular framework is

$$MSE_i(r^*) - MSE_{i-1}(r^*) = \sum_{j=1}^{i-r^*} \alpha_{ji}^2 \sigma^2 - \sum_{j=1}^{i-1-r^*} \alpha_{j,i-1}^2 \sigma^2 > 0. \quad (16)$$

(16) means that the price stickiness among industries are different and the price rigidity depends on the impact of indirectly linked industries on industry price. If the size of demand variance is the same over the industries, the degree of price rigidity increases in the indirect backward linkages. We get a testable hypothesis on the accumulation of price rigidity. (16) also implies that the prices of downstream industries tend to be stickier than those of upstream industries in this particular input-output system. This is because downstream industries have greater impacts of upstream industries and they adjust prices only partially to those impacts because of the lack in information. This result means that the price stickiness accumulates when prices are adjusted through a complex input-output system and eventually the prices of finished products will take a considerable degree of rigidity. The implication is consistent with Blanchard's "cumulation hypothesis" (Blanchard (1987)).

III. AN EMPIRICAL TEST OF THE ACCUMULATION OF PRICE RIGIDITY

In this section, I test an important implication of the model, the relation between price rigidities of industries and interindustry linkages. First, industry price equation is estimated by using a partial adjustment model that includes unit material and labor cost, and a lagged price term. The equilibrium price equation of an industry is specified simply in a linear form as follows:⁷

$$P^*_{it} = b_0 + b_1 UMC_{it} + b_2 ULC_{it} \quad (17)$$

⁷ Price equation (1) can be derived from a general equilibrium model of monopolistic competitive economy in which consists of worker-firms as in Blanchard and Kiyotaki(1987) and Ball and Romer(1989). Price equation (17) can be derived from a general equilibrium model of monopolistic competitive economy in which each firm employs Leontief production function. So the two price equations are related and equation (1) implies that it includes unit material cost and unit labor cost.

where UMC is the unit material cost, and ULC is the unit labor cost. We assume that in any quarter the actual price moves according to the partial adjustment mechanism

$$P_{it} - P_{it-1} = \mu_i (P_{it}^* - P_{it-1}), \quad 0 < \mu_i < 1. \quad (18)$$

Substituting the equilibrium price into this adjustment mechanism gives us the equation

$$P_{it} = \mu_i b_0 + \mu_i b_1 UMC_{it} + \mu_i b_2 ULC_{it} + (1 - \mu_i) P_{it-1} + \varepsilon_t \quad (19)$$

where ε_t is an error term. Equation (19) is a regression equation that needs an error term. So an error term is introduced exogenously in this regression equation. A preliminary estimation in the levels reveals the nonstationarity of error terms. Following Nelson and Plosser(1982), equation (19) is estimated in the first difference. The two-stage regression is employed to get consistent estimates because of correlation between a lagged price and error term. In the first stage, industry price is regressed on the current, one-period lagged, and two-period lagged cost variables in the first difference. In the second stage, a lagged price term is replaced by the predicted value generated from the first stage regression. Then iteration is used to remove the first-order serial correlation. Fifty-five price equations are estimated using quarterly U.S. industry data. The coefficient estimate on a lagged price term $1 - \mu_i$ is considered the degree of price stickiness in the industry.

Secondly, the cross section regression equation is estimated. The relation between the price stickiness and interindustry linkages (14) is modified in order to accommodate both the econometric and theoretical model. The partial adjustment coefficient μ_i can be related to the impacts of shocks as follows: (18) is transformed to

$$\begin{aligned} 1 - \mu_i &= \frac{P_{it}^* - P_{it}}{P_{it}^* - P_{it-1}} \\ &= \frac{P_{it}^* - P_{it}}{(P_{it}^* - P_{it-1}^*) + (P_{it-1}^* - P_{it-1})}. \end{aligned} \quad (20)$$

The denominator in (20) is the unadjusted part of equilibrium price at time t . The numerator in (20) is decomposed into two terms. The first term in the numerator is total part of price to be adjusted at time t and the second term is the unadjusted part at time $t-1$.

Using (14) and (20), the relation between the price stickiness and the impacts on price can be set up as

$$1 - \mu_i = f \left(\frac{\sum_{j=1}^{i-r^*} \alpha_{ji}^2 \sigma^2}{\sum_{j=1}^i \alpha_{ji}^2 \sigma^2 + \sum_{j=1}^{i-r^*} \alpha_{ji}^2 \sigma^2} \right) \quad (21)$$

where $f(\cdot)$ is a nonlinear function. Define the right hand side variable as *RUIMP* that means the ratio of the unadjusted portion to total impacts on an industry price. Equation (21) is not rigorously derived from (20) and (14). However, we can express (20) in a different way, using (14); Equation (14) and the denominator in (21) means the unadjusted impact on price at time t as well as the stickiness of price. The denominator in (20) is the unadjusted part of price at time t , as mentioned in the above paragraph. So we can match the denominator in (20) to that of (21). The first term in the numerator in (21) is total impacts at time t . The second term in the numerator in (21) is the unadjusted impact at time $t-1$. In the same way, the first and second term in the numerator in (20) are related to the first and second term in the numerator in (21), respectively. According to (21), the price stickiness increases in the degree of the impact of industry-specific shocks relevant to the optimal level of information r^* . As before, I may infer that the industries relevant to r^* are the directly linked industries to the i -th industry.

The proxy variables for the various interindustry impacts can be found in input-output literature. The price models in the input-output literature have extensively studied the interindustrial impact on industry price (Miller and Blair(1985)). A proxy variable for the total impact is total backward linkage coefficient in the input-output analysis literature. Total backward linkage measures total impact of upstream industries on an industry price. Indirect backward linkage measures the impact of indirectly linked industries on an industry price. The row vectors of the total and indirect backward linkages of the industries are defined by

$$TBLS = e[(I-A)^{-1}]^{*2} \text{ and} \quad (22a)$$

$$IBLS = TBLS - eA^{*2} \quad (22b)$$

respectively where A is an direct input coefficient matrix, I is the identity matrix, $[(I-A)^{-1}]^{*2}$ is the element-wise squares of $(I-A)^{-1}$, A^{*2} is the elementwise squares of A , and e is a unit row vector. $(I-A)^{-1}$ and A are elementwise squared because the various impacts on industries are the squared form in (21). The total backward linkage measures of the i -th industry, $TBLS_i$, is the i -th element of a row vector $TBLS$. The indirect backward linkage measures of the i -th industry, $IBLS_i$, is the i -th element of a row vector $IBLS$. Therefore, the proxy for *RUIMP* is

$$RUIMP_i = \frac{IBLS_i}{TBLS_i + IBLS_i} \quad (23)$$

Therefore, the resulting cross-section regression equation is

$$1 - \mu_i = \gamma RUIMP_i^{1/2} + u_i, \quad 0 < RUIMP_i < 1 \quad (24)$$

where u_i is an error term. To accommodate the nonlinearity in the relation between price stickiness and interindustry linkages as shown in (11), equation (24) is estimated in square root form with and without a constant term. Use of estimates causes heteroscedasticity in the error term. Therefore, the weighted least squares is applied to estimate equation (24).

IV. TEST RESULTS AND THEIR IMPLICATION

The first difference form of equation (19) is estimated by the ordinary least squares or two stage regression when there are cases of serial correlation in residuals. Table 1 presents the time series estimates of price dynamics for fifty five sample industries. In almost all equations the coefficient estimates of material cost have the correct sign and seventy two percent of those equations with the correct sign are statistically significant at the five or ten percent level. Thirty five of the fifty five coefficient estimates of labor cost variable are positive and about one third of these coefficients are statistically significant. Seven out of fifty five estimates, however, show a statistically significant negative sign. The long-term wage contracts and indexation practices, together with the increased labor productivity, in many of these sectors might have produced these estimates. The most important coefficient is that of the lagged price level. Forty five of these inertia coefficient estimates are positive and less than one, and also many of these (thirty two) estimates are statistically significant at the conventional level. The negative coefficients on the lagged price are statistically insignificant except three cases.

Table 2 shows that there is remarkably significant positive relation between the industry's price stickiness and the unadjusted impact of other industries. With equations 1 and 2, both significant and insignificant stickiness estimates (forty five) are regressed on RUIMP. With equations 3 and 4, only significant stickiness estimates (thirty two) are used in the regression. The coefficient is positive as predicted by the model. The bias seems to stem from specification errors such as the assumption of identical variances in industry-specific shocks, omission of demand variable, and other elasticities. The result implies that the price rigidity accumulates when individual prices pass through a complex input-output system (Blanchard(1987)). Therefore, finished product prices will respond more gradually to changes in monetary shocks, input prices, and wages

than the prices in earlier stages of processing. Price rigidity is built into an input-output system so that it is not easily removed without full information on a number of linkages, and cost and demand shocks.

[Table 1] Estimates of Price Equations

Industry	Constant	<i>DUMC</i>	<i>DULC</i>	<i>DP</i>	R^2	Durbin-h	Est. Method
Iron Ores Mining	-0.136 (-0.15)	1.518 (3.78)	2.288 (1.06)	-0.140 (-0.47)	0.326	-2.89	CO
Coal Mining	-2.033 (-1.31)	2.524 (6.39)	5.564 (0.85)	0.341 (3.72)	0.637	-0.48	OLS
Crude Petroleum&Gas	-6.189 (-1.77)	7.823 (5.30)	24.530 (1.68)	0.303 (2.25)	0.522	-4.39	CO
Stone & Clay Mining	1.087 (1.05)	-0.298 (-2.38)	-0.295 (-0.08)	0.862 (3.75)	0.350	-	CO
Food	0.010 (0.01)	1.422 (15.61)	-5.465 (-0.8)	0.078 (1.30)	0.825	0.77	OLS
Tobacco	3.821 (2.45)	1.064 (3.38)	2.674 (0.82)	-0.234 (-0.88)	0.202	0.79	OLS
Broad & Narrow Fabrics	-0.491 (-0.72)	0.946 (7.47)	3.233 (0.90)	-0.048 (-0.39)	0.642	3.33	CO
Misc. Textile Goods	0.462 (1.05)	0.414 (3.16)	-4.818 (-1.33)	0.293 (1.32)	0.319	-2.51	CO
Apparel	-0.017 (-0.06)	0.378 (2.86)	4.437 (1.36)	0.507 (3.20)	0.509	-2.94	CO
Misc. Fabricated Textile Products	1.259 (1.13)	-0.414 (-1.16)	0.976 (0.27)	0.762 (2.26)	0.238	-	CO
Wood & Lumber	-1.739 (-1.81)	3.013 (15.36)	-5.841 (-0.72)	-0.061 (1.07)	0.830	-1.02	OLS
Wood Containers	-0.597 (-0.70)	0.335 (2.61)	4.675 (0.75)	0.822 (3.49)	0.264	-6.17	CO
Household Containers	0.313 (0.52)	0.125 (0.96)	-8.163 (-0.92)	1.005 (4.15)	0.285	-	CO
Other Furniture	0.769 (0.65)	0.181 (0.93)	8.018 (0.57)	0.491 (1.80)	0.124	-1.70	CO
Paper	1.689 (1.90)	1.204 (5.40)	-12.308 (-2.30)	0.247 (2.21)	0.496	-0.99	OLS
Paperboard Containers	0.304 (0.32)	1.064 (4.69)	-3.903 (-0.50)	0.076 (0.40)	0.405	-	CO

[Table 1] (continued)

Industry	Constant	<i>DUMC</i>	<i>DULC</i>	<i>DP</i>	R^2	Durbin-h	Est. Method
Chemical	0.019 (0.02)	1.787 (12.11)	-17.477 (-2.58)	0.222 (3.36)	0.869	0.95	OLS
Plastics & Synthetic	0.713 (0.50)	1.322 (7.70)	-7.772 (-0.97)	0.063 (0.52)	0.735	3.61	CO
Drugs & Cleaning Preparations	-0.588 (-1.20)	0.652 (5.18)	11.686 (3.35)	0.050 (0.44)	0.572	-0.65	OLS
Paints	0.824 (1.15)	1.006 (7.73)	1.178 (0.28)	-0.040 (-0.38)	0.585	-1.09	OLS
Petroleum Refining	0.635 (0.17)	1.135 (6.79)	-28.268 (-1.99)	0.176 (1.28)	0.554	-1.88	CO
Rubber & Misc. Plastic Products	0.306 (0.43)	0.633 (3.87)	5.620 (1.13)	0.213 (1.19)	0.346	-	CO
Leather Tanning	-4.179 (-0.66)	5.913 (5.11)	-55.80 (-0.99)	0.031 (0.27)	0.307	0.62	OLS
Footwear & Leather Products	-0.068 (-0.14)	0.175 (4.22)	14.431 (2.73)	0.561 (5.92)	0.522	-1.53	OLS
Glass Products	0.196 (0.19)	0.350 (1.81)	19.976 (2.28)	0.122 (0.54)	0.280	-	CO
Stone & Clay Products	1.935 (2.08)	0.915 (4.08)	-22.262 (-3.22)	0.592 (2.71)	0.414	-	CO
Primary Iron	0.180 (0.18)	0.658 (3.77)	8.502 (1.54)	0.298 (2.72)	0.389	-0.52	OLS
Primary Nonferrous Metals	-0.969 (-1.24)	2.265 (20.38)	-10.099 (-2.08)	-0.018 (0.36)	0.899	-2.41	CO
Metal Containers	-0.450 (-0.45)	0.671 (3.64)	7.099 (1.62)	0.456 (3.48)	0.346	-	CO
Fabricated Structural Metals	0.536 (0.64)	0.266 (2.34)	4.287 (0.60)	0.546 (4.95)	0.408	-1.12	OLS
Screw Machine Products	0.532 (0.29)	-0.057 (-2.52)	17.790 (1.82)	0.201 (0.70)	0.388	2.14	CO
Other Fabricated Metal Products	0.255 (0.45)	0.101 (1.42)	5.159 (0.90)	0.709 (3.99)	0.339	-	CO
Engines & Turbines	0.572 (0.92)	-0.014 (-0.76)	4.863 (2.12)	0.681 (6.93)	0.488	-0.63	OLS

[Table 1] (continued)

Industry	Constant	<i>DUMC</i>	<i>DULC</i>	<i>DP</i>	R^2	Durbin-h	Est. Method
Farm Machinery	1.605 (0.08)	0.085 (2.46)	1.238 (0.77)	0.524 (4.35)	0.30	-0.46	OLS
Construction & Mining Machinery	0.987 (1.80)	0.105 (1.17)	0.222 (0.27)	0.726 (7.63)	0.560	-0.96	OLS
Materials Handling Machinery	1.004 (2.21)	0.038 (1.35)	1.100 (1.50)	0.613 (5.77)	0.399	-1.29	OLS
Metal Working Machinery	1.132 (2.26)	-0.026 (-1.20)	2.301 (1.42)	0.684 (6.93)	0.494	0.44	OLS
Special Industry Machinery	1.482 (2.24)	0.018 (0.91)	-1.468 (-0.34)	0.679 (5.75)	0.382	0.80	OLS
General Industrial Machinery	0.717 (1.26)	0.053 (1.89)	1.652 (0.36)	0.731 (7.30)	0.554	1.18	OLS
Misc. Machinery	1.417 (1.08)	-0.010 (-0.65)	28.158 (2.84)	0.215 (1.67)	0.168	-1.32	OLS
Office & Computing Machines	0.153 (0.63)	0.128 (1.53)	-1.273 (-0.63)	0.711 (2.85)	0.129	-	CO
Service Industry Machinery	1.286 (2.53)	0.069 (2.04)	0.096 (0.03)	0.227 (1.68)	0.064	-1.45	OLS
Electrical Industrial Equip	0.077 (0.13)	0.124 (1.13)	6.315 (0.93)	0.648 (3.46)	0.334	-1.79	CO
Household Appliances	0.386 (0.99)	0.095 (1.07)	4.279 (2.32)	0.475 (3.90)	0.266	-0.98	OLS
Electrical Lighting & Wiring	0.300 (0.31)	0.061 (0.41)	8.581 (1.23)	0.697 (3.38)	0.369	-3.00	CO
TV & Communication Equipment	-0.013 (-0.03)	0.073 (0.86)	-2.436 (-0.70)	0.144 (0.36)	0.030	-	CO
Electronic Components	0.964 (1.72)	0.214 (1.73)	0.004 (1.77)	0.270 (1.11)	0.247	-2.49	CO
Misc. Electrical Machinery	0.753 (1.04)	0.037 (0.25)	-2.561 (-0.67)	0.830 (4.28)	0.352	-2.75	CO
Motor Vehicles	1.404 (2.29)	-0.080 (-0.88)	8.604 (3.63)	0.091 (0.72)	0.175	0.15	OLS
Aircraft	-0.909 (-0.66)	0.460 (4.64)	17.785 (2.17)	0.410 (2.81)	0.479	-4.69	CO

[Table 1] (continued)

Industry	Constant	<i>DUMC</i>	<i>DULC</i>	<i>DP</i>	R^2	Durbin-h	Est. Method
Other Transportation Equipment	3.118 (3.68)	0.077 (0.96)	-8.380 (-2.01)	0.535 (4.30)	0.243	-1.57	OLS
Scientific Instruments	5.163 (3.58)	-0.706 (-6.49)	-2.741 (-0.39)	-0.418 (-3.47)	0.353	7.25	CO
Optical & Photographic Equip.	-2.198 (-1.30)	2.830 (4.90)	2.857 (0.21)	-0.269 (-2.36)	0.330	-	OLS
Misc. Manufacturing	-4.875 (-2.47)	2.835 (5.99)	49.906 (2.40)	-0.243 (-2.31)	0.444	0.02	OLS
Utility	9.932 (4.62)	0.379 (2.35)	-58.402 (-6.31)	0.519 (3.35)	0.513	-	CO

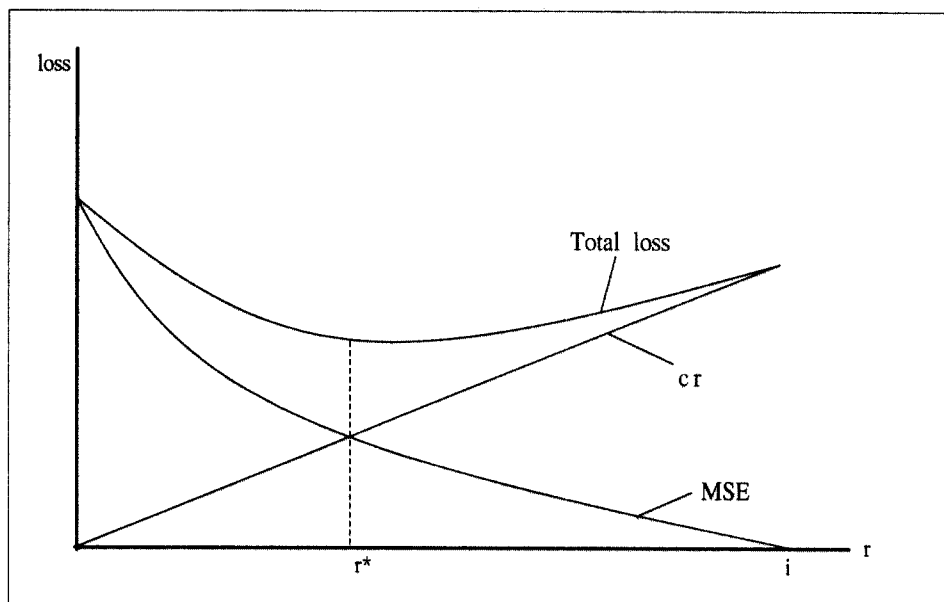
1. *DUMC* is the first difference in average material cost, *DULC* is the first difference in average labor cost, and *DP* is the first difference in a lagged price.
2. OLS is the ordinary least squares and CO is a modified Cochrane-Orcutt method for serial correlation correction in the presence of a lagged endogenous variable.
3. The Durbin-h statistics in CO are obtained from ordinary least squares estimation.
4. The numbers in parentheses are t-statistics.
5. "-" indicates that the value is not available.
6. R^2 is the adjusted value.

[Table 2] Determinant for the Accumulation of Price Rigidity

Equation	Constant	$RUIMP^{1/2}$	R^2
1	-9.266 (-2.45)	13.803 (2.56)	0.740
2	-	0.562 (10.56)	0.711
3	-2.337 (-0.28)	4.068 (0.34)	0.875
4	-	0.738 (15.28)	0.879

1. The numbers in parentheses are t-statistics.
2. "-" indicates that the value is not available.
3. R^2 is the adjusted value.

[Figure]



V. CONCLUDING REMARK

I adopt a framework in which firms face the scarcity of information when they set prices. New Keynesian theory simply assumes that a small menu cost prevents prices from being continuously and fully adjusted. This study shows that the adjustment cost is largely the cost of collecting and processing information on demand or cost in the sectors linked to each industry, and its marginal cost turns out to be very large, contrary to the assumption imposed on New Keynesian models.

Firms choose to be incompletely informed when they make search of information because of a large marginal cost and drastically decreasing marginal benefits of information search. That is, they cannot adjust prices fully to the current state of economy-wide and industry-specific conditions. As a result, nominal rigidity stems from economic agents' optimal decisions. The information scarcity justifies discrete change of nominal price. It also rationalizes staggering of prices as a device for information acquisition in a more general dynamic setting (Ball and Cecchetti(1988)). This analytical framework yields an interesting implication that the price stickiness varies across industries. Most importantly, the rigidities accumulate when individual prices are adjusted through a complex input-output system, and the final good prices take a considerable stickiness, comparing to raw material and intermediate product prices. The result gives a microeconomic foundation for the gradual adjustment of the aggregate price level.

DATA DESCRIPTION AND SOURCE

Input-output table: I took the 1977 81×81 direct input coefficient table from Current Survey of Business, Bureau of Economic Analysis hoping that this mid-point industrial structure will represent the entire time period. Fifty-five industries were selected from the input-output table based on the conformity between the price data (Producer Price Index) and the input-output table industry classification.

Material cost: The quarterly time series data cover the period of 1971.III-1984.IV. Producer Price indexes are published by the Bureau of Labor-Statistics. Mid-quarter data are used. Adjusting the PPI classification and the input-output table classification of the industries, the direct-input-coefficient-weighted averages of UMC are calculated for each quarter.

Labor cost: Hourly average earnings, prepared by the Bureau of Labor Statistics, are used as the unit labor cost. Most series match those classifications of the I-O table.

REFERENCES

- Akerlof, George and Janet Yellen (1985), "A Near-Rational Model of the Business Cycle with Wage and Price Inertia," *Quarterly Journal of Economics*, 100, 823-838.
- Ball, Laurence and Stephen Cecchetti (1988), "Imperfect Information and Staggered Price Setting," *American Economic Review*, 78, 999-1018.
- Ball, Laurence and David Romer (1989), "The Equilibrium and Optimal Timing of Price Changes," *Review of Economic Studies*, 56, 179-198.
- Blanchard, Olivier J. (1987), "Aggregate and Individual Price Adjustment," *Brookings Papers on Economic Activity*, 1 (1987), 57-109.
- Blanchard, O.J. and N. Kiyotaki (1987), "Monopolistic Competition and the Effects of Aggregate Demand," *American Economic Review*, 77(4), 647-666.
- Bordo, Michael (1980), "The Effects of Monetary Change on Relative Commodity Prices and the Role of Long-Term Contracts," *Journal of Political Economy*, 88-6, 1088-1109.
- Carlton, Dennis (1986), "The Rigidity of Prices," *American Economic Review*, 76, 637-658.
- Fethke, Gary and Andrew Policano (1984), "Wage Contingencies, the Pattern of Negotiation, and Aggregate Implications of Alternative Structures," *Journal of Monetary Economics*, 14, 151-170.
- Gordon, R. (1990), "What is New Keynesian Economics?," *Journal of Economic Literature*, September 1990, 28(3), 115-71.
- Gray, Jo Anna (1978), "On Indexation and Contract Length," *Journal of Political Economy*, 91, 1-18.
- Mankiw, N. Gregory (1985), "Small Menu Costs and Large Business Cycles," *Quarterly Journal of Economics*, 100, 529-537.
- Miller, Ronald E. and Peter D. Blair (1985), *Input-Output Analysis*, Prentice Hall, Inc., Englewood Cliffs, NJ.
- Nelson, Charles and Charles Plosser (1982), "Trends and Random Walks in Macroeconomic Time Series," *Journal of Monetary Economics*, 10(1982), 139-162.
- Parkin, Michael (1986), "The Output-Inflation Trade-off When Prices Are Costly to Change," *Journal of Political Economy*, 94, 200-224.
- Roberts, John M. (1995), "New Keynesian Economics and the Phillips Curve," *Journal of Money, Credit, and Banking*, 27, 975-984.
- Roberts, John M., David J. Stockton, and Charles S. Struckmeyer (1994), "An Evaluation of the Sources of Aggregate Price Rigidity," *Review of Economics and Statistics*, 76, 142-50.