ECONOMIC RESEARCH REPORTS

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RR # 91-44

August, 1991

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First version: June 1990.

Revised: June 1991

JEL Classification: D21, D43, D92.

We acknowledge support from the C.V.Starr Center for Applied Economics at New York University. We would like to thank M.I. Nadiri, G. Mankiw, M. Salinger, and the participants in seminars at the NBER, IGIER, Boston University and Padova University for useful comments. M.Galeotti acknowledges financial support from the Ministero della Pubblica Istruzione.

Abstract

In this paper we investigate the degree of market power in U.S. manufacturing industries and whether that power is affected by fluctuations in demand. The key feature of our contribution is that it imposes on a model with adjustment costs the minimum structure necessary to recover a measure of the markup of output price over marginal cost. The markup is allowed to vary with fluctuations in demand, and its estimate is obtained using the Euler equation approach. The paper also presents evidence on the degree of returns to scale. We conduct the empirical investigation for U.S. two-digit manufacturing industries using annual data covering 1952 through 1985. Significant departures from perfect competition characterize a large number of U.S. industries. However, our estimates suggest that the markups are smaller than those found in studies that abstract from adjustment costs. In general, fluctuations in demand do not have a powerful effect on the degree of market power. In a few industries markups are significantly lower when the level of industry demand is above normal, while in a few others markups are higher when the aggregate economy is expanding.

1. Introduction

How large and significant is the departure from perfect competition in the output market? How do demand fluctuations affect market power? These are the main questions we address in this paper; we do so by estimating a dynamic model of the firm that allows for adjustment costs and a variable markup.

The literature on the estimation of the degree of market power is vast (see Bresnahan, 1989, for a critical review). Most papers that are based on estimates of the optimality conditions for input demands typically assume that all factors of production are variable (Appelbaum, 1979; Gollop and Roberts, 1979; Appelbaum, 1982). Hall (1986, 1988, 1989) has proposed a different approach based on the reassessment of Solow's productivity residual.[1] He shows that imperfect competition in the product market generates procyclical residuals when factor shares are measured relative to total revenue. The derivation of the model is based on a short-run profit function in which the firm optimizes the use of labor, while the capital stock is taken as given. When factor shares are measured relative to total costs, a procyclical residual is consistent with an increasing returns technology. In this case Hall assumes that capital is a perfectly variable factor of production.

The model of the firm that underlies these estimates is static since when capital is taken as given or as perfectly variable. This is rather limiting. In fact, the firm will adjust the capital stock optimally over time, but there are costs associated with changing its level. Moreover, there may be costs in adjusting the labor input as well, and these costs may be interrelated with those for capital (Nadiri and Rosen, 1969). The existence of adjustment costs requires that we model firms' choices in a dynamic setting.

In this paper we estimate a convenient version of the Euler equation for this problem that does not require us to parametrize the gross production function or the cost function of the firm. We assume that the firm faces a

1. Other authors have pursued Hall's line of research. See Shapiro (1987), Domowitz, Hubbard and Petersen (1988), and Caballero and Lyons (1989).

downward sloping demand curve for its product and that adjustment costs are internal and additively separable. Our intent is to impose on the problem the minimum structure needed to recover a measure of markup of price over marginal cost. Nonconstant returns to scale, at least of a certain type, can be accommodated into the framework and, in principle, estimated. Our contribution is close in spirit to those of Galeotti and Schiantarelli (1988), Morrison (1990), and Chirinko and Fazzari (1991). These papers allow for imperfect competition and adjustment costs for labor and capital. Contrary to Morrison and Chirinko and Fazzari, however, we do not need to parametrize the variable cost and gross production functions respectively. Contrary to Galeotti and Schiantarelli and to Chirinko and Fazzari we do not use the average market value of the firm as a regressor. This last feature also characterizes the contribution by Bond and Meghir (1990) who use a model that allows adjustment costs for capital but not for labor.

A crucial feature of our model is that it permits the markup to vary over the cycle. In the empirical application, the markup is assumed to vary with the discrepancy between actual demand and its normal level. This dependence can have either a discrete or a continuous representation. If discrete, the markup takes only two values, depending on whether demand is higher or lower than normal. We also discuss the effect on the price cost margin of whether demand is rising or falling. The cyclical behavior of market power is an important issue with implications for the transmission mechanism of aggregate demand variations (see Rotemberg and Woodford, 1991). It also may be of interest in assessing various models of oligopoly conduct (see also Domowitz, Hubbard, and Petersen, 1987, and Bresnahan, 1989).

In Section 2 we illustrate the theoretical model starting from the simplest version: capital is the only quasi-fixed factor and returns to scale are constant. In Section 3 we extend the model to allow for nonconstant returns to scale and for the quasi-fixity of labor. In all cases we assume that materials are a variable input and we define firm's production in terms of gross output. In Section 4, using 1952-1985 data for two-digit manufacturing industries, we present the empirical results concerning adjustment costs parameters and the size and cyclicality of the price cost margin. In addition, we present a test of the constant returns to scale assumption.

We find that imperfect competition is pervasive in U.S. industries, although our estimates of the price cost margin are systematically lower than those obtained using Hall's methodology. Our results also show that in general fluctuations in demand do not have a powerful effect on the degree of market power. In a few industries where it is more cyclical and the parameter estimates are theory consistent, markups are lower when industry demand is above normal. In a few other , markups are higher when the aggregate economy is expanding. Finally, the data suggest that the hypothesis of constant returns to scale in the gross production function cannot be rejected in a majority of industries.

In the Conclusions we summarize the main findings of the paper.

2. The Basic Model with Adjustment Costs for Capital and Constant Returns to Scale

Denote output, capital, the vector of variable inputs (which we take here to be given by labor L and materials M), and investment by Y, K, Z, and I respectively. Assume for the time being that the capital stock is the only quasi-fixed input. The firm's technology is described by the net production function Y = F(K,Z,I).[2] The firm maximizes the following objective function:

$$V_t = E_t\{\sum_{s=0}^{\infty}\beta_{t,s}[(1-\tau_{t+s})p_{t+s}F(K_{t+s},Z_{t+s},I_{t+s}) +$$
$$-(1-\tau_{t+s})p^Z_{t+s}Z_{t+s}-(1-\eta_{t+s})p^I_{t+s}I_{t+s}]+A_t\} \quad (1)$$

2. We assume that investment goods are delivered at the beginning of period t and that they become immediately productive.

where V is the firm's market value, $\beta_{t,s}=\prod_{i=0}^{s}(1+\rho_{t+i})^{-1}$ is the discount factor between period t and period s, ρ is the firm's rate of return, τ_t is the corporate tax rate, p_t is the price of output and a choice variable for the firm, p_t^Z is the vector of variable input prices (namely, w_t and p_t^M are the prices of labor and materials respectively), η_t is the present value of depreciation allowances on a dollar of new investment (inclusive of investment tax credits), and p_t^I is the price of investment goods. A_t denotes the present value of depreciation allowances on investment undertaken before period t, and it is therefore a predetermined variable for the firm.

The firm maximizes (1) subject to the equation of motion for the capital stock:

$$I_t = K_t - (1-\delta)K_{t-1} \tag{2}$$

where δ is the capital depreciation rate.

Assume that adjustment costs are internal and additively separable, so that:

$$F(K_t, Z_t, I_t) = f(K_t, Z_t) - G(I_t, K_t) \tag{3}$$

where F(.) is the "net" production function, f(.) the "gross" production function, and G(.) the cost of adjustment function. Solving the optimization problem summarized by equations (1) and (2) and making use of (3) yields the following Euler equation describing the evolution of the capital stock over time:

$$\frac{1}{1+\mu_t}[f_K(t)-G_K(t)]-u_t=\frac{1}{1+\mu_t}G_I(t)-E_t\left[\frac{1}{1+\mu_{t+1}}\phi_t G_I(t+1)\right] \tag{4}$$

where $\phi_t = (1-\delta)\beta_{t,t+1}(p_{t+1}/p_t)$ is the after tax real rate of discount adjusted for depreciation and u_t is Jorgenson's user cost of capital.[3] μ_t is the markup over marginal cost charged by the firm. Equation (4) simply says that the excess of the marginal revenue of capital over its user cost must be equal in equilibrium to the cost of adjusting the capital stock today, net of the cost saving for not having to adjust tomorrow.

Under the assumption of perfect competition, $\mu_t = 0$, otherwise the definition of the markup depends upon the specific model used to characterize the imperfectly competitive output market. For instance, if the firm is a monopolistic competitor, $1+\mu_t = 1/(1-1/\epsilon_t)$, where ϵ_t is the price elasticity of the demand for its product. With homogeneous products and symmetric Cournot equilibrium, $1+\mu_t = 1/(1-(1/\epsilon_t N))$, where ϵ_t is the price elasticity of industry demand and N is the number of firms. More generally, $1+\mu_t = 1/(1-\theta_t/\epsilon_t)$, where θ_t indexes the degree of competitiveness of the firm's conduct. The further away from zero θ_t is, the greater is the degree of collusion.

To derive an estimable equation from (4), we need to discuss two main issues: are how to parametrize the marginal product of capital, $f_K - G_K$, and the excess of the markup over unity, μ_t. With respect to the first, we want to avoid choosing a specific functional form for the production function. We will start by assuming that there are constant returns to scale in both current production and installation activities. We will analyze the consequences of relaxing this assumption below. If we apply Euler's theorem to (3) and use the first order conditions for the variable inputs, we obtain:

$$F_K(t) = f_K(t) - G_K(t) = (1+\mu_t)\frac{\Pi_t}{p_t K_t} - \mu_t \frac{Y_t}{K_t} + G_I(t)\frac{I_t}{K_t} \qquad (5)$$

3. See the Appendix for the precise expression for u_t.

where Y_t is output and $\Pi_t = (1-\tau_t)p_t F_t - p_t^z Z_t$ is total revenue minus variable costs.[4] Expression (5) can be substituted into the Euler equation (4). No further assumption is needed concerning the gross production function. We only need to parametrize the adjustment cost function, which we do as follows:

$$G(I_t, K_t) = (a/2)[(I_t/K_t) - b]^2 K_t \tag{6}$$

Substituting (5) and (6) into (4) yields the Euler equation for the capital stock, which can be written as follows:[5]

$$\frac{I_t}{K_t} = b\left(1 - \phi_t - \frac{I_t}{K_t}\right) + \left(\frac{I_t}{K_t}\right)^2 + E_t\left(\frac{1+\mu_t}{1+\mu_{t+1}}\phi_t \frac{I_{t+1}}{K_{t+1}}\right) + \frac{1+\mu_t}{a}\left(\frac{\Pi_t}{p_t K_t} - u_t\right) - \frac{\mu_t}{a}\frac{Y_t}{K_t} \tag{7}$$

A simple and attractive option for investigating the cyclical behavior of the markup is to assume that μ_t varies discretely and takes two values, one in periods of high demand, μ^H , and one in periods of low demand, μ^L . We will define periods of high (low) demand as those in which employment or output exceeds (falls below) a centered, five-year moving average.[6] Another alternative is to allow the markup to vary continuously. Denoting with B_t the deviation of industry demand from its "normal" level (in the sense defined above), we could write:

$$\mu_t = m_0 + m_1 B_t \tag{8}$$

4. Notice that (5) recognizes that we do not observe output "gross" of adjustment costs, but only "net" of these costs.

5. If a multiplicative productivity shock is introduced in front of the gross production function, all the derivations go through and (7) still obtains. An additive stochastic shock could also be added inside the quadratic term of the adjustment cost function.

6. Experimentation with a longer moving average has yielded very similar results that will not be reported here.

Both specifications can be made more general by permitting the markup to be affected not only by the level of demand but also by its derivative with respect to time. In the discrete case, one may assume that the markup takes four values according to whether demand is high or low and increasing or decreasing. A derivative effect can also be included easily in equation (8).

In all cases we can recover unique estimates for the structural parameters representing market power and adjustment costs.

3. Extensions: Nonconstant Returns to Scale and Labor as a Quasi-Fixed Factor

What are the consequences for the model just outlined of relaxing the constant returns assumption? There are two possibilities to be considered. The first is to maintain the assumption of linear homogeneity for the adjustment cost function but to allow the gross production function to be homogeneous of degree $1+\gamma$. In other words, there are variable returns to scale in the firm's current production activity, but there are constant returns in the installation activity. Applying Euler's theorem in this case produces the following:

$$F_K(t) = f_K(t) - G_K(t) = (1+\mu_t)\frac{\Pi_t}{p_t K_t} - (\mu_t - \gamma)\frac{Y_t}{K_t} + (1+\gamma)G_I(t)\frac{I_t}{K_t} + \gamma G_K(t) \qquad (9)$$

The Euler equation becomes:

$$\frac{I_t}{K_t} = \frac{b^2\gamma}{2} + b\left[1 - \phi_t - (1+\gamma)\frac{I_t}{K_t}\right] + \left(1+\frac{\gamma}{2}\right)\left(\frac{I_t}{K_t}\right)^2 - E_t\left(\frac{1+\mu_t}{1+\mu_{t+1}}\phi_t\frac{I_{t+1}}{K_{t+1}}\right) +$$
$$+ \frac{1+\mu_t}{a}\left(\frac{\Pi_t}{p_t K_t} - u_t\right) - \frac{\mu_t - \gamma}{a}\frac{Y_t}{K_t} \qquad (10)$$

In principle the model remains identified, and unique estimates can be recovered for all structural parameters.

Assuming instead that the net rather than the gross production function is homogeneous of degree $1+\gamma$, then:

$$F_K(t) = f_K(t) - G_K(t) = (1+\mu_t)\frac{\Pi_t}{p_t K_t} - (\mu_t - \gamma)\frac{Y_t}{K_t} + G_I(t)\frac{I_t}{K_t} \qquad (11)$$

The only change relative to equation (7) is that the coefficient in front of Y_t/K_t becomes $(\gamma-\mu_t)/a$. In this case, the model is underidentified and the parameters of interest cannot be separately estimated. If one erroneously assumes constant returns to scale, the markup will be underestimated when $\gamma > 1$ (increasing returns) and overestimated when $\gamma < 1$.[7] In order to recover the structural parameters of the model, one has to impose more structure. For instance, if it is assumed that firms are monopolistic competitors and a specific form is assumed for the output demand function, the latter can be jointly estimated with the Euler equation for capital (see Galeotti and Schiantarelli, 1988, and Morrison, 1990). However, any departure from the assumption of monopolistic competition makes this approach not very useful. Moreover, the specification and estimation of a satisfactory demand function for the output of each industry considerably complicates the simplicity of our framework; consequently, we will not pursue this approach here.

We can extend the basic model in another direction by assuming that labor is costly to adjust. Then the net production function can be written as:

$$Y_t = F(K_t, L_t, M_t, H_t, I_t, X_t) = f(K_t, L_t, M_t, H_t) - G(I_t, K_t, X_t, L_t) \qquad (12)$$

where M is the (only variable) input from materials, L is the stock of labor (number of employees), H is average hours worked, and X is gross hirings. G(.)

7. This is true whether nonconstant returns to scale characterize the net <u>or</u> the gross production function.

is the internal (additively separable) adjustment cost function that contains both investment and gross hirings (together with K and L) as its arguments. The equation of motion for employment is:

$$X_t = L_t - (1-\xi)L_{t-1} \qquad (13)$$

where ξ is the exogenous quit rate for workers. We are assuming here that adjustment costs for changing the number of workers are far more important than adjustment costs for changing the number of hours; the latter is set equal to zero.[8] However, changes in hours may affect the average cost of a worker because of an overtime premium. We will maintain the hypothesis that the technology is linear homogeneous in (K,L,M,I,X).[9]

The first order conditions for K and I can be combined to yield equation (7) again. From the first order conditions for L and X we can obtain:

$$\frac{1}{1+\mu_t}[f_L(t) - G_L(t)] - \frac{w_t}{p_t} = \frac{1}{1+\mu_t}G_X(t) - E_t\left[\frac{1}{1+\mu_{t+1}}\psi_t G_X(t+1)\right] \qquad (14)$$

where $\psi_t = [(1-\xi)/(1-\delta)]\phi_t$.

For the adjustment cost function G(.) we assume the following quadratic form, which allows for interrelated adjustment costs (additive constants are omitted for simplicity):

8. This hypothesis appears to be reasonable a priori and is supported by empirical evidence (Shapiro, 1986).

9. We are <u>not</u> assuming that the gross production function is linear homogeneous in H as well. We can think of f(.) being written as f(.)=t(H)h(K,L,M,I,X), where h(.) is linear homogeneous in its arguments and no homogeneity restrictions are imposed on t(.).

$$G(I_t, K_t, X_t, L_t) = \frac{a}{2}\left(\frac{I_t}{K_t}\right)^2 K_t + \frac{c}{2}\left(\frac{X_t}{L_t}\right)^2 L_t + s\left(\frac{I_t X_t}{L_t}\right) \tag{15}$$

where a,c, and s are positive constants. In the Appendix we show that using the adjustment cost function in (15) and applying Euler's theorem to (12), equations (7) and (14) can be combined to yield:

$$\begin{aligned}
\frac{I_t}{K_t} = & \left(\frac{I_t}{K_t}\right)^2 + E_t\left(\frac{1+\mu_t}{1+\mu_{t+1}}\phi_t \frac{I_{t+1}}{K_{t+1}}\right) + \frac{1+\mu_t}{a}\left(\frac{\Pi_t}{p_t K_t} - u_t\right) - \frac{\mu_t}{a}\frac{Y_t}{K_t} + \\
& + \frac{c}{a}\left\{\frac{X_t}{L_t}\frac{X_t}{K_t} - \left[\frac{X_t}{L_t} - E_t\left(\frac{1+\mu_t}{1+\mu_{t+1}}\frac{1-\xi}{1-\delta}\phi_t \frac{X_{t+1}}{L_{t+1}}\right)\right]\frac{L_t}{K_t}\right\} + \\
& + \frac{s}{a}\left\{2\frac{X_t}{L_t}\frac{I_t}{K_t} - \left[\frac{X_t}{L_t} - E_t\left(\frac{1+\mu_t}{1+\mu_{t+1}}\frac{1-\xi}{1-\delta}\phi_t \frac{X_{t+1}}{L_{t+1}}\right)\right] + \right. \\
& \left. - \left[\frac{I_t}{L_t} - E_t\left(\frac{1+\mu_t}{1+\mu_{t+1}}\frac{1-\xi}{1-\delta}\phi_t \frac{I_{t+1}}{L_{t+1}}\right)\right]\frac{L_t}{K_t}\right\}
\end{aligned} \tag{16}$$

This is a composite Euler equation for capital and labor that generalizes the basic model, where labor was treated as a variable input (see equation (7)). The basic model can be obtained as a special case of equation (16) by setting c and s equal to zero. The consequences of introducing nonconstant returns to scale for identifying the structural parameters in (16) are identical to the ones already described for the basic model.

4. Empirical Results

Our empirical results are based on the estimation of the Euler equation (7) and its extensions. Expectations of future variables are replaced with their realized values, thereby generating a forecast error orthogonal to the variables in the agents' information set. An instrumental variable procedure is used in estimation (McCallum, 1976). As a check for potential misspecifications, we report Sargan's test aimed at assessing the uncorrelatedness of the instruments with the disturbances.[10]

Using annual data over the period 1952-1985, We estimated the model for 20 U.S.industrial sectors at the two-digit level.[11] The industries, together with their SIC codes, are listed in Table 1. Table 2 presents a summary of the empirical evidence concerning the structural parameters in equation (7) under the assumption that the markup takes two different values, one in periods of high demand and the other in periods of low demand. Demand is "high" ("low") when industry employment exceeds (falls short of) a five-year, centered geometric moving average.[12] More precisely, the classification depends upon the sign of B_t , where:

$$B_t = \log L_t - .25 \log (L_{t-2} L_{t-1} L_{t+1} L_{t+2}) \tag{17}$$

Applying this classification to the 1952-1985 period, there are between twelve and eighteen years of low demand and between sixteen and twenty-two years of high demand. If output had been used instead of employment, a very similar classification of periods of low and high demand would have resulted, and hence very similar empirical results.

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10. We have used instruments dated t-1 or earlier, so that all the parameters were consistently estimated, even if there is a stochastic additive component in the adjustment cost function. The Sargan test is distributed chi-square with degrees of freedom equal to the number of instruments minus the number of regressors.

11. The data are based on series for prices and quantities of gross output, capital, labor, energy, intermediate materials, and purchased services prepared by the Bureau of Labor Statistics. For a detailed description of the data, see Gullickson and Harper (1987).

12. The variable defined in (17) has been used in Bils (1987) in a related context.

For four sectors (SIC 20, 30, 32, and 33) we have used the lagged value of profits instead of its contemporaneous value as a regressor in equation (7). Although not strictly consistent with the model, this modification leaves the sign of the estimated coefficient unchanged but helps to enhance the significance of the profit variable and hence the precision of the estimates.

The overall performance of the equations is satisfactory, and the Sargan statistics are not suggestive of gross misspecification. The consistency with the adjustment cost framework underlying the estimated equation is violated in six of the twenty industries: the estimates of the adjustment cost parameter have the wrong sign for Food and Kindred Products (SIC 20), Lumber and Wood Products (SIC 24), Printing and Publishing (SIC 27), Petroleum and Coal Products (SIC 29), Electric and Electronic Equipment (SIC 36), and Miscellaneous (SIC 39). In all other cases the parameter α has the expected sign, although in several industries it is not significant at conventional levels. μ^H and μ^L are significantly different from zero in fifteen and eleven industries, respectively, at the 5 percent level. In eight industries both μ^H and μ^L are significantly different from zero. The general conclusion is that, in a large number of industries it is necessary to abandon the assumption of a perfectly competitive output market, and that the data support the existence of a significant degree of market power.

The difference between μ^H and μ^L is significant at the 5 percent level in four industries - Lumber and Wood (SIC 24), Furniture and Fixtures (SIC 25), Leather (SIC 31), and Instruments and Related Products (SIC 38) - and at the 10 percent level in four additional industries - Food and Kindred Products (SIC 20), Textile (SIC 22), Printing and Publishing (SIC 27), and Fabricated Metal Products (SIC 34). In half of these eight industries (SIC 20, 25, 31, 34) $\mu^H-\mu^L$ is positive, while in the other half (SIC 22, 24, 27, 38) it is negative. In three cases in which $\mu^H-\mu^L$ is positive, the adjustment cost parameter is negative, and hence the model is not theory consistent.

Summarizing, in most cases fluctuations in demand do not have a powerful effect on the markup. When the effect is significant and the model acceptable, the markup tends to vary countercyclically.

In order to assess the robustness of our results with respect to alternative specifications of the degree of market power, in Table 3 we allow the markup to vary continuously as a function of the level of demand relative to normal, as specified in (7). Again we use the variable B_t defined in (17) as a demand indicator. The overall picture is similar to the one in Table 2. The fixed component of μ_t, defined by m_0, is significantly different from zero in fourteen sectors, suggesting that the departure from perfect competition is quite generalized. The set of sectors for which the cyclical variability of the markup is important (as identified by the significance of m_1) almost coincides with the one identified in Table 2; hence, the previous comments on the sign of the cyclical components also apply here. The size of markups is very similar for both sets of results, as can be seen from the average markup figures reported in the two tables. A comparison with previous studies based on Hall's methodology suggests that our model with adjustment costs tends to yield smaller price cost margins. For instance, our results imply an average price cost margin of .24 for the entire manufacturing sector; Hall (1988) obtained a markup slightly above .57, while Domowitz et al. (1988), .58.[13]

So far we have allowed the markup to depend upon the level of demand. We also tested whether price cost margins may be affected by the change in demand (in percentage terms) relative to its trend. When industry employment or output are used to calculate rates of growth, there is no evidence of a significant derivative effect, either in the discrete or in the continuous specification. As an alternative, we allowed the markup to depend on (in addition to the

13. The markups estimated by Hall have been transformed from a value added to a gross output basis to render the comparison meaningful. Domowitz, Hubbard, and Petersen (1988) use Hall's methodology but rely on more disaggregated data and use a gross output technology with materials as an additional input. Both Hall and Domowitz et al. obtain their results under the assumption of constant returns to scale.

level of industry demand) whether the aggregate economy is expanding or contracting; we used the classification of periods of expansions and recessions that Hamilton (1989) has provided.[14]

Table 4 presents the results obtained with a discrete specification of the markup in which μ_t can be thought of as the sum of two additive components, one capturing the level effect (μ^H and μ^L) and the other the derivative effect (μ^E and μ^R). That is:

$$\mu_t = \mu^H(1 - D_t^B) + \mu^L D_t^B + \mu^E(1 - D_t^A) + \mu^R D_t^A \qquad (18)$$

where D_t^B is a dummy variable equal to one (zero) if industry demand is lower (higher) than normal and D_t^A is a dummy variable equal to one (zero) when the economy is in a recession (expansion).

In only seven sectors (the ones reported in the table) is the derivative effect, $\mu^R - \mu^E$, significant. In the five cases in which the adjustment cost parameter is correctly signed (Tobacco (SIC 21), Apparel and other Textile Products (SIC 23), Stone, Clay, and Glass (SIC 32), Transportation Equipment (SIC 37), and Miscellaneous (SIC 39)) the markup in expansions is higher than in recessions, given the level of demand. In these five industries the effect of the level of demand, represented by $\mu^L - \mu^H$, is not significant now and was not significant according to the results of Table 2.

The evidence discussed so far has been obtained under the assumption of constant returns to scale. If we continue to assume linear homogeneity of the adjustment cost technology, while permitting an arbitrary degree of scale returns equal to $(1+\gamma)$ in the "gross" output production activity, then (9) is

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14. Hamilton uses a Markov switching regression to characterize changes in the parameters of the autoregressive process for U.S. real GNP. He obtains estimates of the quarters of recessions remarkably similar to the NBER dating of business cycle. We define a recession year as one in which there has been more than one quarter of negative GNP growth. In our sample period there were ten years of recession.

the appropriate Euler equation and the parameters γ and μ can be separately identified. We have pursued this option empirically, but there was not enough variability in the data to yield reliable estimates of the returns to scale parameter together with the other structural coefficients. We can, however, conduct a formal statistical test of the hypothesis that $\gamma = 0$, in other words, of constant returns in the "gross" production function, using the appropriate Lagrange Multiplier test.

Table 5 reports our findings.[15] The constant returns to scale hypothesis is rejected for four industries at the 5 percent significance level, while for an additional three sectors the hypothesis can be rejected at the 10 percent level. This suggests that the assumption of constant returns to scale is not too misleading for at least two thirds of the industries we have analyzed and that, therefore, we have not seriously underestimated the degree of market power in those cases.[16]

Another extension of the model is to allow labor to be a quasi-fixed factor of production. Under the assumption of constant returns to scale, (16) is the appropriate Euler equation. We have estimated (16) for all industries, and in most cases the adjustment cost parameters are not significant. In Table 6 we report, as an example, estimates for the six industries (Lumber and Wood (SIC 24), Furniture and Fixtures (SIC 25), Rubber and Miscellaneous Plastic Products (SIC 30), Leather (SIC 31), Stone, Clay, and Glass (SIC 32), Primary Metal (SIC 33)) in which labor adjustment costs appear to play some role in the model with binary markups.[17] The adjustment cost parameters for capital, a, and for labor, c, are correctly signed, and the sign of interrelation parameter s suggests that it pays to adjust capital and labor at the same

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15. The test is based on the model of Table 2 that uses the binary markup. The results are not sensitive to the specification of the markup.

16. In contrast, Morrison (1990) and Chirinko and Fazzari (1991) find empirical support in favor of increasing returns to scale.

17. Similar results are obtained using different specifications for μ_t .

time.[18] Compared to the case when labor is treated as a variable input (see Table 2), the markups tend to be marginally higher now, but the difference between μ^H and μ^L is less significant. This fact reinforces the conclusion that the data do not present strong evidence in favor of a variable markup.

The general macroeconomic implication of our results is that changes in the degree of market power are not a powerful channel for the transmission of aggregate demand shocks to factor demand. Moreover, the data do not allow us to discriminate sharply between different models of industry conduct having different implications for the cyclical behavior of the markup, in the sense that margins are higher when demand is low relative to normal. In only four industries are the adjustment cost parameters correctly signed <u>and</u> is there some evidence in favor of countercyclical behavior of the markup. This is consistent with the supergame model of oligopoly behavior by Rotemberg and Saloner (1986) and Rotemberg and Woodford (1988, 1991), and not consistent with the model by Green and Porter (1984).[19] The countercyclical margins we find from a very limited set of industries are also consistent with the model by Chatterjee and Cooper (1988) which, under Nash equilibrium, generates procyclical entry in an industry and hence a countercyclical markup. In a few industries, the markup is higher in expansions than in recessions. This is a finding of some interest. However, the overall evidence is not in favor of a large degree of markup variability as a function of either the level or direction of the change in demand. This conclusion differs from the one reached by Bils (1987) and by Rotemberg and Woodford (1991) using models that abstract from adjustment costs for capital. Their estimates strongly imply

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18. Note that the parameter α was wrongly signed for industry 24 when labor was treated as a variable input, as reported in Table 2.

19. The basic idea in the first group of papers is that, in periods of high demand, the benefits from deviations from the collusive solution increase, and hence the latter can be supported as an optimal strategy only if prices and markups are low. In the Green and Porter model information about demand is imperfect and reversion to the one shot Cournot equilibrium will sometimes occur simply because of low demand. This will generate procyclical price cost margins.

countercyclical variations in market power. Using industry data and average variable costs to calculate the markup, Domowitz, Hubbard, and Petersen (1988) obtain mixed results. In particular, markups are strongly procyclical in concentrated industries and more weakly procyclical in unconcentrated industries using the degree of capacity utilization as a proxy for demand. However, price movements are countercyclical, particularly in industries with high price cost margins. Morrison (1990) finds that the sign and significance of the correlation between markups and demand fluctuations depend upon the variable chosen to capture the strength of demand, but is significant when a capacity utilization measure is used. Finally, based upon firm by firm data, Chirinko and Fazzari (1991) find that price cost margins are higher when the rate industry-demand growth is above average in eight out of the twelve four-digit industries under study.[20] The evidence contained in these studies in favor of cyclical variations in market power contrasts with our result that markups are relatively insensitive with respect to demand fluctuations.

5. Conclusions

In this paper we have examined the issue of market power in a model with adjustment costs. Working with U.S. manufacturing data disaggregated at the two-digit level, we have found that the departure from perfect competition characterizes a large number of U.S. industries. However, our estimates suggest that the markups are smaller than those suggested by studies that abstract from adjustment costs. Moreover, we do not find evidence for a generalized rejection of the constant returns to scale hypothesis. Our results also throw light on the cyclical behavior of the markup. It appears that fluctuations in

20. Both Morrison's model and Chirinko and Fazzari's model allow for adjustment costs for capital and labor, variable markups, and nonconstant returns to scale. Unlike ours, both models rely upon explicit parametrizations of either the cost or the production function. Morrison assumes also that the demand function faced by the firm coincides with the industry demand function.

the level of demand do not have a powerful effect on the markup. In the limited number of industries where there is a significant effect and the adjustment cost parameters have the sign implied by the theory, the markup tends to vary countercyclically. However, given the strength of demand, in a few industries the markup is higher in expansions than in recessions. Nevertheless, the general impression is that variations in the degree of market power are not an important channel through which fluctuations in aggregate demand for the firm product are transmitted to factor demand. These results are robust to different specifications of the markup as a discrete or continuous function of demand and to different assumptions concerning the nature of adjustment costs.

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Appendix

In this appendix we derive the Euler equation for the model with both labor and capital as quasi-fixed factors, as given in equation (16) in the main text. The Euler equation when labor is a variable factor (equation (7) in the main text) is a special case of (16).

Where labor is a quasi-fixed input, the firm's objective function can be written as:

$$V_t = E_t\{\sum_{s=0}^{\infty} \beta_{t,s}[(1-\tau_{t+s})p_{t+s}(f(t+s)-G(t+s))+$$

$$-(1-\tau_{t+s})p^M_{t+s}M_{t+s} - \bar{w}_{t+s}X_{t+s} - (1-\eta_{t+s})p^I_{t+s}I_{t+s}] + A_t - C_t\} \quad (A1)$$

where the production function is given in (12). p^M_t and M_t denote the price and quantity of material inputs. C_t is the present value of labor costs of workers hired before time t, which is predetermined as of time t, and $\bar{w}_{t+s}$ is the present value of labor costs of workers hired from time t+s onward. Specifically:

$$\bar{w}_{t+s} = \sum_{v=t+s}^{\infty} \beta_{t+s+1,v}(1-\tau_v)w_v(1-\xi)^{v-(t+s)} \quad (A2)$$

where $\beta_{t+s+1,t+s} = 1$ .Given the equations of motion (2) and (13), the first order conditions for M, I, K, X, and L at time t can be written compactly as:

$$E_t\{f_M(t) - (1+\mu_t)(p^M_t/p_t)\} = 0 \quad (A3)$$

$$E_t\{(1+\mu_t)^{-1}(1-\tau_t)p_t[f_K(t)-G_K(t)-G_I(t)] - (1-\eta_t)p^I_t +$$

$$+\beta_{t,t+1}(1-\delta)[(1+\mu_{t+1})^{-1}(1-\tau_{t+1})p_{t+1}G_I(t+1) - (1-\eta_{t+1})p^I_{t+1}]\} = 0 \quad (A4)$$

$$E_t\{(1+\mu_t)^{-1}(1-\tau_t)p_t[f_L(t)-G_L(t)-G_X(t)]-\overline{w}_t+ \\ +\beta_{t,t+1}(1-\xi)[(1+\mu_{t+1})^{-1}(1-\tau_{t+1})p_{t+1}G_X(t+1)-\overline{w}_{t+1}]\}=0 \qquad (A5)$$

Taking forward differences of (A2), we see that:

$$E_t[\overline{w}_t-\beta_{t,t+1}(1-\xi)\overline{w}_{t+1}]=(1-\tau_t)w_t \qquad (A6)$$

Substitution into (A5) yields:

$$E_t\{(1+\mu_t)^{-1}(1-\tau_t)p_t[f_L(t)-G_L(t)-G_X(t)]-(1-\tau_t)w_t+ \\ +\beta_{t,t+1}(1-\xi)[(1+\mu_{t+1})^{-1}(1-\tau_{t+1})p_{t+1}G_X(t+1)]\}=0 \qquad (A7)$$

Applying Euler's theorem to the production function given in (13), assumed to be linear homogeneous in K, L, M, I, and X, and using conditions (A3) and (A7), one obtains:

$$F_K(t)=f_K(t)-G_K(t)=\frac{Y_t}{K_t}-[G_X(t)-\psi_t G_X(t+1)]\frac{L_t}{K_t}+ \\ -(1+\mu_t)\frac{w_t L_t}{p_t K_t}-(1+\mu_t)\frac{p_t^M M_t}{p_t K_t}+G_I(t)\frac{I_t}{K_t}+G_X(t)\frac{X_t}{K_t} \qquad (A8)$$

Add and subtract $(1+\mu_t)Y_t/K_t$ to the above expression and substitute in (A4). Next, define Jorgenson's user cost of capital from (A4) as follows:

$$u_t=\left[\frac{(1-\eta_t)p_t^I}{(1-\tau_t)p_t}-\phi_t\frac{(1-\eta_{t+1})p_{t+1}^I}{(1-\tau_{t+1})p_{t+1}}\right] \qquad (A9)$$

Parametrizing the adjustment cost function G(.) as in equation (15) in the main text, one obtains equation (16), i.e.:

$$\frac{I_t}{K_t}=\left(\frac{I_t}{K_t}\right)^2+E_t\left(\frac{1+\mu_t}{1+\mu_{t+1}}\phi_t\frac{I_{t+1}}{K_{t+1}}\right)+\frac{1+\mu_t}{a}\left(\frac{\Pi_t}{p_tK_t}-u_t\right)-\frac{\mu_t}{a}\frac{Y_t}{K_t}+$$

$$+\frac{c}{a}\left\{\frac{X_t}{L_t}\frac{X_t}{K_t}-\left[\frac{X_t}{L_t}-E_t\left(\frac{1+\mu_t}{1+\mu_{t+1}}\frac{1-\xi}{1-\delta}\phi_t\frac{X_{t+1}}{L_{t+1}}\right)\right]\frac{L_t}{K_t}\right\}+$$

$$+\frac{s}{a}\left\{2\frac{X_t}{L_t}\frac{I_t}{K_t}-\left[\frac{X_t}{L_t}-E_t\left(\frac{1+\mu_t}{1+\mu_{t+1}}\frac{1-\xi}{1-\delta}\phi_t\frac{X_{t+1}}{L_{t+1}}\right)\right]+\right.$$

$$\left.-\left[\frac{I_t}{L_t}-E_t\left(\frac{1+\mu_t}{1+\mu_{t+1}}\frac{1-\xi}{1-\delta}\phi_t\frac{I_{t+1}}{L_{t+1}}\right)\right]\frac{L_t}{K_t}\right\} \qquad (A10)$$

where $\Pi_t=(1-\tau_t)\{p_t[f(t)-G(t)]-p_t^M M_t-w_tL_t\}$. Equation (7) in the main text (when b=0) can be obtained by setting c and s equal to zero in (A10).

If nonconstant returns to scale of degree $1+\gamma$ in the gross production function are allowed, then (A10) becomes:

$$\frac{I_t}{K_t}=\left(1+\frac{\gamma}{2}\right)\left(\frac{I_t}{K_t}\right)^2-E_t\left(\frac{1+\mu_t}{1+\mu_{t+1}}\phi_t\frac{I_{t+1}}{K_{t+1}}\right)+\frac{1+\mu_t}{a}\left(\frac{\Pi_t}{p_tK_t}-u_t\right)-\frac{\mu_t-\gamma}{a}\frac{Y_t}{K_t}+$$

$$+\frac{c}{a}\left\{\frac{X_t}{L_t}\frac{X_t}{K_t}-\left[\frac{X_t}{L_t}-E_t\left(\frac{1+\mu_t}{1+\mu_{t+1}}\frac{1-\xi}{1-\delta}\phi_t\frac{X_{t+1}}{L_{t+1}}\right)\right]\frac{L_t}{K_t}\right\}+$$

$$+\frac{s}{a}\left\{2\frac{X_t}{L_t}\frac{I_t}{K_t}-\left[\frac{X_t}{L_t}-E_t\left(\frac{1+\mu_t}{1+\mu_{t+1}}\frac{1-\xi}{1-\delta}\phi_t\frac{X_{t+1}}{L_{t+1}}\right)\right]+\right.$$

$$\left.-\left[\frac{I_t}{L_t}-E_t\left(\frac{1+\mu_t}{1+\mu_{t+1}}\frac{1-\xi}{1-\delta}\phi_t\frac{I_{t+1}}{L_{t+1}}\right)\right]\frac{L_t}{K_t}\right\} \qquad (A11)$$

When $\gamma=0$, (A11) reduces to (A10).

Table 1: SIC Codes for Two-digit U.S. Industries.

SIC 20:	Food and Kindred Products
SIC 21:	Tobacco Manufactures
SIC 22:	Textile Mill Products
SIC 23:	Apparel and Other Textile Products
SIC 24:	Lumber and Wood Products
SIC 25:	Furniture and Fixtures
SIC 26:	Paper and Allied Products
SIC 27:	Printing and Publishing
SIC 28:	Chemical and Allied Products
SIC 29:	Petroleum and Coal Products
SIC 30:	Rubber and Miscellaneous Plastic Products
SIC 31:	Leather and Leather Products
SIC 32:	Stone, Clay, and Glass Products
SIC 33:	Primary Metal Industries
SIC 34:	Fabricated Metal Products
SIC 35:	Machinery, except Electrical
SIC 36:	Electric and Electronic Equipment
SIC 37:	Transportation Equipment
SIC 38:	Instruments and Related Products
SIC 39:	Miscellaneous Manufacturing Industries

Table 2: Estimated Coefficients of the Model with the Binary Demand Indicator for the Markup and Labor as a Variable Input.*

Sector Code	μ^H	μ^L	$\mu^H - \mu^L$	Average μ
20	.188 (23.66)	.171 (23.65)	.017 (1.87)	.18
21	1.675 (4.55)	1.595 (4.07)	.079 (0.24)	1.63
22	-.007 (0.11)	.218 (2.67)	-.225 (1.73)	.12
23	.126 (9.68)	.172 (7.38)	-.046 (1.43)	.15
24	.146 (4.51)	.013 (0.50)	.133 (3.99)	.09
25	.068 (2.21)	.192 (4.80)	-.123 (1.97)	.13
26	.129 (1.12)	.251 (1.93)	-.122 (1.41)	.20
27	.165 (6.32)	.118 (2.64)	.047 (1.78)	.14
28	.055 (0.23)	.720 (1.45)	-.665 (1.39)	.26
29	.106 (1.58)	.041 (0.51)	.065 (0.85)	.07
30	.112 (1.89)	.260 (2.97)	-.148 (1.42)	.17
31	.047 (1.49)	.221 (6.15)	-.173 (2.84)	.15
32	.121 (2.13)	.271 (2.22)	-.151 (1.02)	.20
33	-.000 (0.01)	.129 (2.01)	-.130 (1.44)	.07
34	-.021 (0.30)	.430 (1.99)	-.451 (1.77)	.21
35	.034 (0.47)	.326 (2.67)	-.292 (1.62)	.18
36	.124 (2.87)	.024 (0.41)	.100 (1.88)	.06
37	.025 (0.26)	.417 (1.93)	-.391 (1.45)	.29
38	.460 (2.36)	.246 (1.10)	.214 (2.75)	.34
39	.170 (3.22)	.118 (3.74)	.051 (1.20)	.14

(*) (i) Sample period: 1952-1985. (ii) The demand indicator variable B(t) is defined in equation (17) in the text and the markup can take two values, μ^L and μ^H. (iii) Asymptotic t-ratios in parentheses, computed from robust standard errors. (iv) The Sargan test for misspecification is distributed as chi-square with number of degrees of freedom reported in parentheses. The values differ because for some sectors the constant in the adjustment cost function has been set to zero (see equation (7) in the text). (v) The list of instruments is: constant, $(I/K)_{t-1}$, $(I/K)_{t-2}$, $(Y/K)_{t-1}$, $(Y/K)_{t-2}$, τ_{t-1}, η_{t-1}, u_{t-1}, u_{t-2}, K_{t-1}, K_{t-2}, $[(\Pi/pK)-u]_{t-2}$, $[(I/K)-(I/K)^2]_{t-2}$, $[(wL+p^M M)/pK]_{t-2}$, $1-\phi_{t-2}-(I/K)_{t-2}$, $(X/L)_{t-2}$, $(X/K)_{t-2}$, $(L/K)_{t-2}$, X_{t-2}. (vi) The average markup is calculated as a weighted average of markups, where the weights are the number of periods of high and low demand.

Table 2 (continued)

Sector Code	α	Durbin Watson	Sargan Test (d.f.)
20	-18.209 (3.65)	2.30	18.00 (17)
21	177.150 (1.06)	2.26	9.12 (17)
22	10.900 (2.78)	1.72	12.13 (17)
23	17.655 (2.63)	1.71	13.94 (17)
24	-13.684 (2.90)	2.05	16.54 (17)
25	23.445 (2.94)	1.69	15.86 (17)
26	52.301 (0.70)	1.77	16.62 (16)
27	-29.505 (1.32)	2.03	17.26 (17)
28	150.310 (0.86)	1.36	16.88 (16)
29	-53.031 (1.25)	1.47	19.17 (17)
30	20.543 (1.42)	2.38	13.22 (16)
31	33.730 (4.00)	1.86	17.44 (17)
32	19.825 (1.24)	1.97	15.40 (17)
33	21.309 (1.40)	1.75	17.31 (16)
34	99.911 (1.58)	1.97	10.29 (16)
35	38.603 (1.50)	2.07	13.75 (16)
36	-25.733 (1.54)	1.94	14.94 (16)
37	56.642 (1.38)	2.22	8.69 (16)
38	68.959 (1.04)	1.97	15.99 (17)
39	-34.068 (1.01)	2.49	19.51 (17)

Table 3: Estimated Coefficients of the Model with the Continuous Demand Indicator for the Markup and Labor as a Variable Input.*

Sector Code	m_0	m_1	Average μ
20	.180 (27.38)	1.033 (2.34)	.18
21	1.489 (16.01)	-.070 (0.01)	1.49
22	.168 (1.65)	-6.149 (1.27)	.18
23	.145 (19.72)	-.559 (1.19)	.14
24	.079 (2.22)	1.898 (3.56)	.07
25	.102 (4.60)	1.917 (2.77)	.10
26	.165 (1.65)	-4.972 (0.91)	.16
27	.140 (2.96)	2.745 (1.80)	.14
28	.523 (2.12)	-29.693 (1.56)	.49
29	.058 (0.67)	8.250 (1.48)	.07
30	.183 (5.72)	-2.002 (0.96)	.19
31	.126 (7.30)	-3.054 (2.03)	.12
32	.175 (3.00)	-2.780 (1.03)	.18
33	.106 (1.54)	-2.004 (1.38)	.10
34	.154 (3.81)	-4.260 (1.52)	.16
35	.140 (14.25)	1.463 (6.72)	.14
36	.116 (4.43)	1.419 (3.84)	.11
37	.203 (2.18)	-6.258 (1.39)	.21
38	.112 (0.93)	1.723 (2.03)	.11
39	.242 (0.80)	-9.265 (0.78)	.24

(*) See Table 2. The markup is defined as: $\mu_t = m_0 + m_1 B_t$. The average μ is the mean value of the sample.

Table 4: Estimated Coefficients of the Model with the Markup Depending upon Level and Derivative Demand Effects.*

Sector Code	$\mu^H + \mu^E$	$\mu^L - \mu^H$	$\mu^R - \mu^E$
20	.180 (15.28)	-.011 (0.93)	.021 (2.25)
21	1.134 (7.41)	-.205 (0.68)	-.440 (2.71)
23	.465 (2.01)	-.330 (3.02)	-.230 (1.97)
32	.334 (1.31)	.199 (0.41)	-.471 (2.05)
37	.509 (1.45)	.107 (0.31)	-.712 (2.37)
39	.163 (5.01)	.025 (0.38)	-.183 (3.16)

Sector Code	α	Durbin Watson	Sargan Test (d.f.)
20	-22.946 (3.33)	2.29	16.71 (17)
21	123.42 (2.38)	1.74	15.52 (17)
23	220.11 (1.13)	2.24	9.87 (17)
32	48.035 (2.06)	1.73	14.15 (16)
37	97.825 (1.21)	2.01	14.66 (16)
39	21.466 (1.33)	2.57	16.79 (16)

(*) Notes: See Table 2. The definition of the markup is:

$$\mu_t = \mu^H(1 - D_t^B) + \mu^L D_t^B + \mu^E(1 - D_t^A) + \mu^R D_t^A$$

where D_t^B is a dummy variable equal to one (zero) if industry demand is lower (higher) than normal and D_t^A is a dummy variable equal to one (zero) when the economy is in a recession (expansion).

Table 5: Lagrange Multiplier Test of the Constant Returns to Scale Hypothesis.*

Sector Codes	Test Statistics
20	0.007
21	0.084
22	3.625+
23	0.853
24	4.597*
25	7.800*
26	4.824*
27	2.695+
28	1.975
29	1.134
30	0.079
31	0.223
32	0.704
33	3.721+
34	0.041
35	0.011
36	0.359
37	0.135
38	3.642+
39	7.549*

(*) Notes: The test is based on the model of Table 2. An asterisk (cross) indicates that the constant returns to scale hypothesis can be rejected at the 5% (10%) significance level.

Table 6: Estimated Coefficients of the Model with the Binary Demand Indicator for the Markup and Labor as a Quasi-fixed Input.*

Sector Code	μ^H	μ^L	$\mu^H - \mu^L$	α
24	.184(2.07)	.225(1.94)	-.042(0.30)	24.115(1.61)
25	.134(2.44)	.193(3.06)	-.064(0.59)	23.290(1.67)
30	.191(20.43)	.215(14.19)	-.015(1.05)	7.620(3.71)
31	.136(3.67)	.229(5.64)	-.093(1.50)	36.198(3.45)
32	.293(2.35)	.395(2.30)	-.102(1.52)	26.151(1.44)
33	.152(2.28)	.246(2.51)	-.094(1.46)	18.513(1.72)

Sector Code	c	s	Durbin Watson	Sargan Test (d.f.)
24	221.23(1.39)	-15.782(1.42)	2.15	12.38 (15)
25	68.365(2.08)	-8.360(2.06)	1.78	14.11 (15)
30	78.106(2.12)	-4.484(3.16)	1.97	12.26 (14)
31	95.884(2.81)	-21.523(2.83)	1.51	16.28 (15)
32	343.37(1.49)	-13.020(1.44)	1.75	13.57 (14)
33	318.62(1.76)	-7.741(1.75)	1.79	16.57 (14)

(*) Notes: See Table 2.