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# The cyclical behavior of mark ups in U.S. manufacturing and trade: new empirical evidence based on a model of optimal storage

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**Abstract**

An Euler condition for optimal inventory accumulation is used to obtain information on the behavior of mark ups of price over marginal cost in U.S. manufacturing and trade. Data at the two-digit SIC level are used. Mark ups appear to be procyclical in most of the two-digit SIC sectors. © 1997 Elsevier Science S.A.

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## 1. Introduction

Much research has been devoted to the cyclical behavior of mark ups of price over marginal cost, but no consensus has been reached on whether mark ups are pro- or countercyclical. The goal of the present paper is to provide new empirical evidence on this issue. Information about the cyclical pattern of mark ups is important because it may allow to discriminate between alternative models of firm and market behavior and between alternative business cycle models that assume imperfect competition in goods markets (see, e.g., Rotemberg and Woodford, 1991 for discussions of these points and for detailed Refs. to the relevant literature)[1]. The key difficulty in computing mark ups of price over marginal cost is the fact that marginal cost is not directly observable. Several methods of estimating marginal cost have been explored, with differing empirical implications concerning the cyclical behavior of the latter.[2]

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[1]Many reasons have been advanced why mark ups might vary over the cycle (e.g., the price elasticity of demand, firms' ability to collude, and the risk of entry by new competitors might be different in recessions than in booms). Early discussions include Harrod (1936), who believed that mark ups are procyclical and Kalecki (1938) and Keynes (1939), who argued that they are countercyclical; among recent models of oligopoly behavior, the Green and Porter (1984) model generates procyclical mark ups, while the Rotemberg and Saloner (1984) model gives rise to countercyclical mark ups.

[2]For a sample of the different methods that have been used, see, e.g., Bils (1987); Rotemberg and Woodford (1991); Morrisson (1993); Domowitz et al. (1986) Domowitz et al. (1988) and Chirinko and Fazzari (1994). The first three studies suggest that mark ups are countercyclical, while the work by Domowitz et al. suggests that they are generally procyclical (particularly in highly concentrated industries); the study by Chirinko et al. likewise suggests procyclicality of mark ups.


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The present paper proposes a new approach for studying the cyclical behavior of mark ups. The approach exploits the prediction that an optimizing firm that sells a storable good equates the marginal cost of that good ‘‘today’’ to the expected discounted marginal cost in future periods (minus the marginal cost of storage). The paper shows that this Euler condition can be used to extract information on the behavior of mark ups from time series on sales prices. This can be achieved without having to estimate a (marginal) cost function.

The approach developed in the paper is applied to sectoral U.S. data for manufacturing, wholesale trade and retail trade. Data for 28 sectors at the two-digit SIC level are used. The results strongly suggest that mark ups are procyclical in most of the two-digit sectors.

Section 2 presents the model on which the empirical analysis is based. In Section 3, the econometric method used in the analysis is discussed. Section 4 presents the data and Section 5 discusses the results.

## 2. Mark ups and optimal storage

A risk neutral firm is considered that sells a storable good. Let $p_t$, $S_t$, $Y_t$ and $C_t(Y_t)$ denote, respectively: the price of the firm's good, the quantity sold, the quantity produced (these variables pertain to period $t$) and the firm's cost of producing $Y_t$ (for a retail or wholesale firm, $Y_t$ is interpreted as purchases of goods for resale). The cost $C_t(Y_t)$ is a convex function of $Y_t$.[3] Also, let $I_t$ denote the firm's stock of finished goods inventories at the end of period $t$. The firm's decision problem is:

$$\text{Max } E_\tau \sum_{t=\tau}^{t=\infty} B_{\tau,t}[p_t S_t - C_t(Y_t)] \tag{1}$$

$$\text{subject to } I_t = I_{t-1} - G_{t-1}(I_{t-1}) + Y_t - S_t \text{ and to } S_t, I_t, Y_t \geq 0 \quad \text{for all } t \geq \tau. \tag{2}$$

Here, $E_\tau$ denotes expectations conditional on information available in period $t$. $B_{\tau,t}$ is the firm's discount factor: $B_{\tau,\tau}=1$ and $B_{\tau,t}=B_{\tau,t-1}\cdot(1/(1+r_{t-1}))$ for $t>\tau$, where $r_{t-1}$ is the one-period discount rate between periods $t-1$ and $t$. Eq. (2) is the law of motion of the firm's stock of inventories (the specification of Eq. (2) follows Miron and Zeldes, 1988). The term $G_{t-1}(I_{t-1})$ represents the cost of storage between periods $t-1$ and $t$. $G_{t-1}(I_{t-1})$ is a convex function of $I_{t-1}$.

A key first-order condition that characterizes an interior solution of the firm's decision problem is:

$$C'_t = E_t(1/(1+r_t)) \cdot C'_{t+1} \cdot (1-\gamma_t), \tag{3}$$

where $C'_t \equiv \partial C_t(Y_t)/\partial Y_t$ is the firm's marginal production cost in period $t$, while $\gamma_t \equiv \partial G_t(I_t)/\partial I_t$ is the marginal cost of storage.[4]

This Euler condition says that marginal production cost in period $t$ is equated, in expected present

[3] As noted by the referee, the model abstracts from cost of adjusting production (the cost $C_t$ depends on date $t$ output, but it does not depend on output in other periods). It is easy to relax that assumption, without altering the key empirical conclusions described below (a detailed discussion of this point is available from the author upon request).

[4] Like much of the existing inventory literature, the analysis here focuses on interior solutions; in the data used below, neither production nor storage falls to zero in any period.

value terms, to marginal cost in $t+1$, net of the marginal cost of storage—i.e., finished goods inventories enable the firm to smooth marginal production cost across time.[5]

If the firm is a price taker in the market for its good, it equates $C'_t$ and $p_t$. The following analysis allows for imperfect competition in goods markets and, hence, for the possibility that price and marginal cost differ. Let $\mu_t$ be the mark up of price over marginal cost:

$$\mu_t \equiv (p_t - C'_t)/C'_t. \tag{4}$$

Using Eq. (4), the Euler condition Eq. (3) can be expressed as:

$$1 = E_t(1/(1+r_t)) \cdot (p_{t+1}/p_t) \cdot ((1+\mu_t)/(1+\mu_{t+1})) \cdot (1-\gamma_t). \tag{5}$$

In what follows, the mark up is parameterized as a function of observable variables. To investigate whether $\mu_t$ varies over the business cycle, the following specification is considered:

$$1 + \mu_t = \exp(b_0 + b_1 \cdot \hat{S}_t + b_2 \cdot \hat{u}_t), \tag{6}$$

where $\hat{S}_t$ and $\hat{u}_t$ denote deviations of the firm's sales and of the national unemployment rate from the respective trend paths of these series (detrended series are used as otherwise the mark up would be non-stationary: sales and the unemployment rate have upward trends in the data set considered below). Specifications similar to Eq. (6) have been considered in several previous studies on mark ups that model the latter as a function of the unemployment rate (or of other measures of the nationwide cycle) and of measures of firm-level (or sectoral) demand (see, e.g., Domowitz et al., 1986). I also experimented with versions of the model in which $\mu_t$ depends on additional macroeconomic variables (namely, on aggregate industrial production and on the interest rate) and with versions in which $\mu_t$ also depends on lagged values of these variables. The key results reported below are robust to these changes in specification.[6]

In the tests below, the marginal cost of storage is assumed to be a linear function of $\hat{I}_t$, the detrended stock of inventories:

$$\gamma_t = a_0 + a_1 \cdot \hat{I}_t, a_1 \geq 0. \tag{7}$$

Using Eqs. (6) and (7), the Euler condition Eq. (5) can be written as:

$$1 = E_t(1/(1+r_t)) \cdot (p_{t+1}/p_t) \cdot \exp(-b_1 \cdot (\hat{S}_{t+1} - \hat{S}_t) - b_2 \cdot (\hat{u}_{t+1} - \hat{u}_t)) \cdot (1 - a_0 - a_1 \cdot \hat{I}_t). \tag{8}$$

[5]Recent empirical research on inventory investment has tested for marginal cost smoothing. Results reported by Kashyap and Wilcox (1993) and Eichenbaum (1989) are consistent with marginal production cost smoothing; however, rejections are reported by Blanchard (1983) and Miron and Zeldes (1988). Each of these tests relies on strong assumptions about the cost function; hence, the rejections that were just mentioned might be due to misspecification of the cost function. The method discussed below uses marginal cost smoothing (Eq. (3)) as a maintained hypothesis, however it does not require estimation of the production cost function.

[6]Following a suggestion made by the referee, a version of the model was also considered in which the marginal cost of storage depends on the inventory to sales ratio ($I/S$), rather than on the stock of inventories alone (see Bils and Kahn (1996) for a possible justification of such a specification). The key results for that variant of the model, and for the alternative specifications mentioned in the preceding paragraph, are available from the author, upon request.

## 3. Econometric methodology

Eq. (8) is estimated and tested using the Generalized Method of Moments (GMM). Let $\eta_{t+1} \equiv 1 - (1/(1+r_t)) \cdot (p_{t+1}/p_t) \cdot \exp(-b_1 \cdot (\hat{S}_{t+1} - \hat{S}_t) - b_2 \cdot (\hat{u}_{t+1} - \hat{u}_t)) \cdot (1 - a_0 - a_1 \cdot \hat{I}_t)$ and $Z_t \equiv (1,\ (1/(1+r_{t-1})) \cdot (p_t/p_{t-1}),\ \hat{S}_t,\ \hat{I}_t,\ \hat{u}_t,\ (1/(1+r_{t-2})) \cdot (p_{t-1}/p_{t-2}),\ \hat{S}_{t-1},\ \hat{I}_{t-1},\ \hat{u}_{t-1})$. Note that Eq. (8) implies that $E_t \eta_{t+1} = 0$. The GMM tests presented below use the orthogonality condition

$$E\{\eta_{t+1} \cdot Z_t\} = 0, \tag{9}$$

and the following first-moment conditions: $\sigma_S^2 = E\{\hat{S}_t^2\}$, $\sigma_u^2 = E\{\hat{u}_t^2\}$, $\sigma_{IP}^2 = E\{\hat{IP}_t^2\}$,

$$\sigma_{S,u} = E\{\hat{S}_t \cdot \hat{u}_t\},\ \sigma_{S,IP} = E\{\hat{S}_t \cdot \hat{IP}_t\},\ \sigma_{u,IP} = E\{\hat{u}_t \cdot \hat{IP}_t\}. \tag{10}$$

Here, $\hat{IP}_t$ denotes detrended national industrial production. $\sigma_S^2$, $\sigma_u^2$, $\sigma_{IP}^2$, $\sigma_{S,u}$, $\sigma_{S,IP}$ and $\sigma_{u,IP}$ are variances and covariances of detrended sales, the detrended unemployment rate and of detrended aggregate industrial production (N.B. because these series are detrended, they have zero means). The GMM estimates presented below are based on the assumption that $\hat{S}_t^2$, $\hat{u}_t^2$, $\hat{IP}_t^2$, $\hat{S}_t \cdot \hat{u}_t$, $\hat{S}_t \cdot \hat{IP}_t$ and $\hat{u}_t \cdot \hat{IP}_t$ are MA(12) processes, i.e. that $E_{t-13}\hat{S}_t^2 = 0$ etc.

To assess the cyclicality of the mark up, the correlation between $\mu$ and the (detrended) unemployment rate, as well as the correlation between $\mu$ and (detrended) aggregate U.S. industrial production will be estimated. Denote these correlations by $\rho_{\mu,u}$ and $\rho_{\mu,IP}$, respectively. Applying GMM to Eqs. (9) and (10) jointly allows to test statistical hypotheses regarding $\rho_{\mu,u}$ and $\rho_{\mu,IP}$. $\rho_{\mu,u}$ and $\rho_{\mu,IP}$ are functions of $b_1$, $b_2$, $\sigma_S^2$, $\sigma_u^2$, $\sigma_{IP}^2$, $\sigma_{S,u}$ $\sigma_{S,IP}$ and of $\sigma_{u,IP}$. Applying GMM to Eqs. (9) and (10) yields estimates of these eight parameters, as well as a covariance matrix for these estimates, which allows to conduct Wald tests concerning $\rho_{\mu,u}$ and $\rho_{\mu,IP}$.

Note that use of Eq. (9) alone (without Eq. (10)) suffices to test the Euler condition Eq. (8). In fact, use of Eq. (9) alone yields estimates of $b_1$ and $b_2$ and tests of overidentifying restrictions that are very similar to those reported below. To save space, only results that jointly use Eqs. (9) and (10) are hence presented.

## 4. The data

The Euler condition Eq. (8) is tested using sectoral data on prices, sales and inventories for 28 subsectors of U.S. manufacturing, wholesale trade and retail trade. The sectors are defined at the two-digit SIC level (a description of the sectors is provided in Appendix A). Monthly time series for the period 1967:M1–1994:M9 are used (estimation results based on annual data are similar to those described below). All data on prices, sales and inventories are from the Bureau of Economic Analysis and from the Census Bureau. The series for sales and inventories are in constant dollars. All series (except the interest rate) are seasonally adjusted. Inventories are measured at the end of each month and they represent stocks of finished goods. The measure for $r_t$ used in the tests is the U.S. prime loan rate (series FYPR from Citibase). The measures for $IP_t$ and $u_t$ are aggregate U.S. industrial production and the national U.S. unemployment rate, respectively (series IP and LHUR from Citibase). All time series, except those for prices and the interest rate, were detrended by regressing logarithms of the series on a quadratic time trend.

## 5. Findings

Table 1 presents the results. Column (1) lists the sectors. Columns (2) to (4) report estimates of the parameters $b_1$, $b_2$ and $a_1$. Column (5) presents probability values of Hansen (1982) $J$ test of the

Table 1
GMM estimation results: monthly data (1967:M1–1994:M9)

| (1) Sector | (2) $b_1$ | (3) $b_2$ | (4) $a_1 \cdot 10^2$ | (5) $p$-value of $J$ test | (6) $\rho_{\mu,u}$ | (7) $\rho_{\mu,IP}$ |
|---|---|---|---|---|---|---|
| Manufacturing | | | | | | |
| 20 | −0.38 (0.12)** | −0.10 (0.13) | 0.10 (2.27) | 0.39 | −0.88 (0.00) | 0.55 (0.12) |
| 21 | −0.05 (0.02)* | 0.35 (0.21)‡ | 0.87 (0.80)§ | 0.18 | 0.99 (0.00) | −0.85 (0.00) |
| 22 | −0.00 (0.09) | −0.37 (0.06)** | 0.68 (1.25) | 0.13 | −0.99 (0.00) | 0.79 (0.00) |
| 23 | −0.03 (0.04)§ | −0.11 (0.05)* | 0.35 (0.71) | 0.53 | −0.99 (0.00) | 0.78 (0.00) |
| 24 | 0.00 (0.11) | −0.52 (0.12)** | −0.54 (1.79) | 0.02 | −0.99 (0.00) | 0.84 (0.00) |
| 25 | −0.06 (0.05)§ | −0.10 (0.04)** | 3.46 (1.47)** | 0.19 | −0.98 (0.00) | 0.76 (0.00) |
| 26 | −0.35 (0.24)* | −0.13 (0.18) | −6.09 (3.76)* | 0.06 | −0.83 (0.09) | 0.46 (0.47) |
| 27 | 0.05 (0.04)§ | −0.01 (0.05) | 0.75 (0.87)§ | 0.58 | −0.91 (0.00) | 0.68 (0.02) |
| 28 | −0.32 (0.28)§ | −0.00 (0.22) | −2.76 (3.47) | 0.17 | 0.36 (0.88) | −0.56 (0.75) |
| 29 | −1.77 (0.34)** | 0.33 (0.89) | −7.85 (5.93)‡ | 0.26 | 0.56 (0.47) | −0.61 (0.26) |
| 30 | −0.25 (0.09)** | −0.05 (0.07) | 1.48 (0.89)* | 0.04 | −0.02 (0.97) | −0.30 (0.63) |
| 31 | −0.02 (0.03) | −0.19 (0.08)** | 0.14 (1.15) | 0.06 | −0.99 (0.00) | 0.83 (0.00) |
| 32 | −0.05 (0.09) | −0.16 (0.20) | 0.65 (5.95) | 0.69 | −0.99 (0.00) | 0.78 (0.00) |
| 33 | −0.19 (0.12)‡ | −0.36 (0.25)‡ | −3.77 (2.38)‡ | 0.07 | −0.93 (0.00) | 0.62 (0.00) |
| 34 | −0.06 (0.07)§ | −0.10 (0.05)* | −0.95 (1.74) | 0.21 | −0.98 (0.00) | 0.69 (0.00) |
| 35 | −0.19 (0.23)§ | 0.12 (0.19) | −6.87 (4.63)‡ | 0.68 | 0.85 (0.02) | −0.90 (0.00) |
| 36 | 0.03 (0.13) | −0.04 (0.06) | −0.68 (1.87) | 0.89 | −0.92 (0.00) | 0.87 (0.00) |
| 37 | −0.05 (0.08) | −0.05 (0.14) | 0.41 (2.12) | 0.06 | −0.82 (0.61) | 0.58 (0.76) |
| 38 | −0.18 (0.08)* | −0.09 (0.11)§ | 0.85 (0.75)§ | 0.32 | −0.89 (0.00) | 0.68 (0.07) |
| 39 | −0.14 (0.07)* | 0.00 (0.17) | 4.25 (2.32)* | 0.63 | 0.36 (0.87) | −0.58 (0.71) |
| Wholesale trade | | | | | | |
| 50 | 0.00 (0.15) | −0.17 (0.07)* | 5.79 (2.24)** | 0.66 | −0.99 (0.00) | 0.82 (0.00) |
| 51 | −0.25 (0.11)* | −0.05 (0.17) | 5.02 (2.87)* | 0.15 | −0.68 (0.73) | 0.49 (0.78) |
| Retail trade | | | | | | |
| 52 | 0.00 (0.09) | −0.19 (0.05)** | 0.10 (1.00) | 0.18 | −0.99 (0.00) | 0.84 (0.00) |
| 53 | 0.69 (0.09)** | −0.13 (0.06)* | 1.93 (1.31)‡ | 0.00 | −0.84 (0.00) | 0.84 (0.00) |
| 54 | −0.14 (0.06)** | 0.01 (0.05) | −1.30 (0.94)‡ | 0.20 | 0.77 (0.04) | −0.50 (0.20) |
| 55 | 0.07 (0.04)‡ | −0.11 (0.04)* | 0.83 (0.54)‡ | 0.11 | −0.96 (0.00) | 0.86 (0.00) |
| 56 | −0.10 (0.12)§ | 0.01 (0.14) | 0.21 (2.78) | 0.17 | −0.80 (0.71) | −0.64 (0.72) |
| 57 | −0.01 (0.08) | −0.11 (0.04)** | 0.84 (1.11) | 0.63 | −0.99 (0.00) | 0.80 (0.00) |

Notes—Column (1): SIC codes.
Columns (2)–(4): parameter estimates; standard errors in parentheses. Estimates of $a_1$ (and corresponding standard errors) are multiplied by 100.
**, *, ‡, §: parameter significant at 1%, 5%, 10% and 20% significance levels respectively (based on one-sided hypothesis tests).
Column (5): the probability value of Hansen's (1982) J test of overidentifying restrictions.
Columns (6)–(7): $\rho_{\mu,u}$ and $\rho_{\mu,IP}$ are the correlation between the mark up and the unemployment rate and the correlation between the mark up and U.S. industrial production, respectively. The figure reported in parentheses next to a given correlation coefficient is the $p$-value of a generalized Wald test of the hypothesis that that correlation equals zero.

overidentifying restrictions implied by conditions Eqs. (9) and (10). The remaining columns show correlations between mark ups and the national unemployment rate ($\rho_{\mu,u}$) and correlations between mark ups and aggregate U.S. industrial production ($\rho_{\mu,IP}$). The figure reported in parentheses next to a given correlation coefficient is the probability value from a generalized Wald test (Amemiya, 1985, p. 145) of the hypothesis that correlation equals zero.

At the 10% level, Hansen (1982) $J$ test fails to reject the model's overidentifying restrictions for 21 of the 28 two-digit sectors (at the 1% level these restrictions fail to be rejected for 27 of the 28 sectors).

Mark ups are generally negatively related to sectoral sales and to the economy-wide unemployment rate ($b_1$ and $b_2$ are negative in most of the two-digit sectors). In roughly three-quarters of the sectors, at least one of the two coefficients $b_1$, $b_2$ is statistically significant at the 10% level. Hence, the hypothesis of a constant mark up is rejected for most two-digit sectors (note also that estimates of $a_1$ are positive in 19 of the 28 two-digit sectors, which is consistent with the assumed convexity of the cost of storage function, $G$; however, these estimates of $a_1$ are often statistically insignificant).

Mark ups are procyclical in a majority of the two-digit sectors: the correlation between the mark up and the unemployment rate ($\rho_{\mu,u}$) is negative for 22 of the 28 manufacturing sectors; 18 of these negative correlations are statistically significant at the 10% level. Positive correlations between mark ups and aggregate industrial production ($\rho_{\mu,IP}$) obtain in 20 of the manufacturing sectors; 16 of these positive correlations are statistically significant at the 10% level. The arithmetic averages of the estimates of $\rho_{\mu,u}$ and of $\rho_{\mu,IP}$ reported for the 28 two-digit sectors are $-0.55$ and 0.34, respectively.

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## Appendix A

### SIC codes for two-digit industries

**Manufacturing**—SIC sector **20**: Food and kindred products; **21**: Tobacco manufactures; **22**: Textile mill products; **23**: Apparel and other textile products; **24**: Lumber and wood; **25**: Furniture and fixtures; **26**: Paper and allied products; **27**: Printing and publishing; **28**: Chemicals and allied products; **29**: Petroleum refining and related industries; **30**: Rubber and miscellaneous plastics products; **31**: Leather and leather products; **32**: Stone, clay, glass, concrete products; **33**: Primary metals industries; **34**: Fabricated metals products; **35**: Machinery, except electrical; **36**: Electrical and electronic equipment; **37**: Transportation equipment; **38:** Instruments and related products; **39:** Miscellaneous manufacturing industries. **Wholesale trade—50**:Wholesale trade—durable goods; **51:** Wholesale trade—nondurable goods. **Retail trade—52**: Building materials, hardware, garden supply, and mobile home dealers; **53**: General merchandise stores; **54**: Food stores; **55**: Automotive dealers and gasoline service stations; **56**: Apparel and accessory stores; **57**: Furniture, home furnishings and equipment stores.

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