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INVENTORY INVESTMENT IN SWEDISH MANUFACTURING FIRMS*

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We derive optimal long-run inventory stocks of finished goods and input materials in a dynamic flexible accelerator model. The predictions are tested on aggregate Swedish manufacturing data using an error correction approach. Cointegration regressions yield stationary relationships and parameter estimates with signs predicted by theory. Error correction estimations show that inventories adjust to long-run levels in a year. The cross effect of excess material inventories on finished goods inventories is strong. Inventory investment subsidies significantly affect finished goods inventory investment. Input deliveries are slow to adjust to new output rates. (JEL E22)

1. *Introduction*

Inventories have attracted the attention of economists for two reasons. One reason is that inventory stocks tie up financial funds, and therefore represent a cost to be included in the firms' optimization of production and sales. This implies that inventory investment might be an important channel for the transmission of monetary policy, since the rate of interest influences the cost of holding inventories.

The other reason is that variations in inventory investment often are large enough to be the most important component in the variations of GNP. This has attracted the interest of policy makers. Inventory investment was a main subtarget of the Swedish stabilization policy during the 1970s.[1]

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[1] *In 1971 the government introduced inventory subsidies to manufacturing and wholesale firms to promote employment. The subsidy was 20 percent of the increased inventory value. The requirements were that the inventory increase consisted of goods produced in Sweden and that*

Three kinds of inventories are often distinguished; finished goods, materials, and goods in process. The paper only deals with the first two. The stock of goods in process in relation to the production level is comparatively stable. It is also probably much less open to independent decisions by firms. Moreover, it is difficult to incorporate more than two stock variables in dynamic analysis.

The objective of this paper is to study the effects of cost and demand disturbances to the short-run variations of finished goods and material inventories. The theoretical analysis concentrates on the decision making of individual firms. The empirical applications concern the aggregate manufacturing industry in Sweden. We estimate error correction models of investment in inventories of finished goods and materials using quarterly data for the period 1972–1989.

Figure 1 shows the ratios between the average stocks in fixed prices of finished goods and material inventories to manufacturing production in Sweden 1972–1989. Both series exhibit cyclical patterns, with peaks in 1977, the second subsidy period, and in 1981–1982.[2] The declines during the 1980s coincide with the introduction of just-in-time techniques. The fluctuations in finished goods stocks are about twice as large as those in materials, although the average size of the two stocks is about the same. Investment in finished goods inventories is therefore more important in explaining variations in GNP.

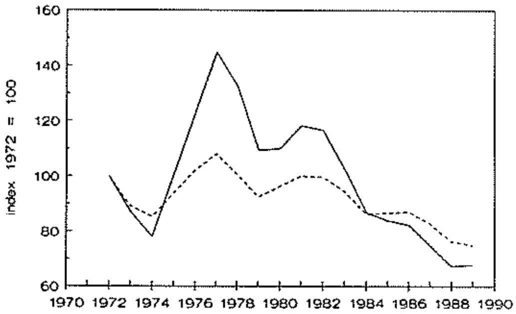

Figure 1. Stocks of finished goods (solid line) and materials (dashed line) relative to output in Swedish manufacturing, 1972–1989.

In the theoretical analysis we use a dynamic flexible accelerator model of a firm.[3] The elements of demand and supply are specified explicitly in the model, which includes both finished goods and material inventories. The firm operates in an output market characterized by monopolistic competition, while it is a price taker in the input markets. The firm maximizes the present value of expected future profits.

In the empirical analysis we estimate adjustment speeds for both kinds of inventories and the effects of cost and demand variables. An elaborate measure of the financial cost of carrying inventories – taking account of taxation, subsidies, and the real interest rate – is introduced [Bergström & Södersten (1984)]. Dummy variables for inventory investment subsidies (1972: 1–1972: 4 and 1975: 3–1976: 4) and for inventory stocks subsidies (1977: 1–1977: 4) capture the additional impact of inventory subsidies apart from the financial effects.

There are good reasons for adopting an error correction approach to the estimation of inventory investment equations. The theoretical model assumes that firms strive to adjust inventory stocks to long-run desired levels. These are, in turn, determined by expected production and inventory holding costs and output demand. The model follows the stock

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the firm did not reduce the number of employees. The subsidy was available throughout 1972. In 1975 the government reintroduced inventory subsidies. It was available during the second half of 1975 and throughout 1976. This time far more than expected, about SEK 1.2 billion, was paid. A public investigation (SOU 1979: 38) concluded that the subsidies had been efficient in promoting employment, since the number of employees in subsidized firms was higher than in non-subsidized firms. It can, however, be argued that the inventory increases would have occurred even without subsidies due to other events during the period.

[2] *It is not possible to determine whether relative stocks increased during the first subsidy period as no comparable pre-1972 inventory data are available.*

[3] *Goodwin (1948) introduced the model. It has been adapted to inventory problems by, e.g., Mills (1957), Darling (1959), Lovell (1961), (1962). Lovell (1964) is an early survey. Early econometric studies found support for the model. The estimated speed of adjustment was, however, surprisingly low. Feldstein & Auerbach (1976) offer the explanation that firms deliberately aim at low rates of adjustment, since firms expect demand shocks partly to be temporary. For a presentation of alternative approaches and possible amendments to the basic model, see Blinder & Maccini (1990), (1991).*

adjustment tradition of inventory research, and so do the error correction models. The error correction procedure leaves it to the data to determine the model's dynamics.[4]

In a first step, we estimate the long-run relationship (single equation cointegration regressions) between inventory stocks and the variables determining optimal stocks, as derived in the theoretical model. The cointegration regressions yield results consistent with the theoretical model. Then, in a second step, we use excess inventories – the differences between the actual inventory stocks and the estimated optimal long-run stocks – as explanatory variables in the investment equations.

2. *A dynamic inventory model of the firm*

As manufacturing firms hold variable finished goods and materials inventories, it is obvious that the quantities produced and sold may differ. Moreover, the quantities of materials bought and put into process also may differ. By using shadow prices of finished goods and material inventories, we can allow for such differences and still make use of the usual criteria for profit maximization. Blinder (1982, 1986) thoroughly demonstrates the technique.

The model, based on the flexible accelerator approach, concentrates on the role of inventories for a profit maximizing manufacturing firm. The firm tries to reach desired levels of the stocks of finished goods and materials. However, the adjustment is not instantaneous, since the adjustment processes are costly. The model highlights these adjustment processes and studies the factors governing them. The general structure of the model, and the mathematical derivation of optimal decision rules, follow Maccini (1984), although he mainly deals with the interaction between finished goods inventories and machinery investment.

The model concentrates on the interaction between the two types of inventories. Disregarding that some inventories exist only for technical reasons, e.g., lack of coordination between production and deliveries, the main reason for holding inventories is to avoid the risk of stockouts. This could lead to sales losses in the short run as well as the long run.[5] The two types of inventories are likely to be substitutes to some extent. A firm facing fluctuating demand may hold finished goods inventories to lessen the risk of having to turn down new orders. Alternatively, it may choose to keep a highly flexible production process. This means that it needs a substantial materials stock to avoid the risk of input stockouts.

A wish to decrease finished goods stocks may imply a reduction in output. This, in turn, is likely to affect both the desired and actual level of the material stocks. It also seems likely, that deviations from the desired level of input stocks affect the stocks of finished goods, since the rate of production affects both stocks. In addition, the interaction between different types of inventories has attracted much attention in the efforts to rationalize inventory management in the last years. This also justifies the emphasis put on the interaction mechanisms in the model.

The firm forms expectations about the exogenous variables – the market demand, the competitors' prices, the wage rate, the material prices, and the interest rate – at the beginning of each planning period. The model is formulated in continuous time. This means that the firm can revise its plans continuously. In this way the problem of unplanned changes in the inventory stocks does not have to be considered. The firm can adjust immediately to changes in the exogenous variables.[6]

Only the technical reasons, which affect production costs, for the inertia in the adjustment of stocks to their desired levels are considered. We disregard the possibility that a change in sales also may be expected to be temporary, and may not call for a full adjustment of stocks.

The use of real capital is treated as constant to emphasize the role of inventories. It unfortunately means that we lose the possibility to investigate the interaction between the inventory levels and the firm's productive capacity in terms of fixed capital.[7]

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[4] *Gustafson (1991), Chapter 3, cannot find empirical support for a structural model derived from theory. The reason may be the dynamic specification implied by theory.*

[5] *The model disregards speculative motives for holding inventories.*

[6] *The results of Feldstein & Auerbach (1976) support this approach.*

[7] *Maccini (1984) and Treadway (1970) are dynamic analyses along this line.*

The firm sells its output in a market characterized by monopolistic competition, while it is assumed to be a price taker in the market for material inputs. The firm maximizes the present value of expected profits defined by

$$(1)\quad PV_t = \int_0^\infty (TR_t - TC_t)\, e^{-rt}\; dt$$

where PV_t is expected present value of future profits, TR_t is expected total revenue, TC_t is expected total variable cost, r is expected rate of interest, and t is time. Output is produced using labor, materials, and a constant capital stock. The production function is defined by

$$(2)\quad Y_t = S L_t^a I_t^b M_t^c - A(\dot{M}_t)$$

where Y_t is gross output, S is a technical constant, L_t is labor input, I_t is input of materials into production, M_t is stock of materials, and $\dot{M}_t$ is the time derivative of material stocks. We assume that $a+b+c=1$; a, b, c > 0; $A(0) = A'(0)=0$; $A'' > 0$; and sign A'=sign $\dot{M}$.

Materials enter the production function in several ways: First, a flow of materials, I_t, is used in the value adding process. Second, material stocks, M_t, play a positive role in preventing bottlenecks in the materials supply from affecting the rate of production. Third, the last term in the output function represents the adjustment cost that occurs because of additional planning and administration, whenever the stock of material inventories is to be altered. If material stocks are changed, the firm looses output as it must use resources that otherwise could have been used in the production of goods.

The assumption of constant returns to scale in production simplifies the analysis. On the one hand, a constant capital stock tends to lower the returns to scale and make an assumption of decreasing returns to scale more realistic. On the other hand, one may suspect that there are economies of scale in the use of materials. The order costs for material shipments are probably independent of the order size. The costs of the physical handling of material inventories may be largely fixed. It is also possible, that the risk of bottlenecks in the material supply increases less than proportionally to the amount of materials bought, particularly if the number of suppliers increases as the firm's material use increases. Since there are arguments pointing toward both increasing and decreasing returns to scale, the assumption of constant returns to scale made in the model may turn out to be reasonable.

The total (variable) cost of the firm is the sum of labor and material costs, that is

$$(3)\quad TC_t = w_t L_t + m_t J_t$$

where w_t is expected wage rate, m_t is expected market price of materials, and J_t is inflow of materials from the firm's suppliers. The volume of expected sales is defined by

$$(4)\quad X_t = B P_t^{-\alpha}\, \Pi_t^{\beta}\, (N/D)_t^{\gamma} D_t$$

where X_t is expected sales, B is a technical constant, P_t is the firm's own price, Π_t is expected average price of competing firms, N_t is stock of finished goods, and D_t is expected market demand. We assume that $\alpha > 1$, $\beta > 0$, and $0 < \gamma < 1$.

Since the firm is supposed to be a monopolistic competitor, it can affect its market share by varying its own price, but it is also dependent on the prices set by its competitors. The firm can reduce the risk of not being able to meet new orders by increasing finished goods inventories relative to expected market demand. In this way, the firm can increase expected sales.

The adjustment cost of finished goods inventories is implicit. The cost of adjusting the rate of output gives rise to increasing marginal costs of production. Changes in the total market demand are assumed to affect all firms proportionally.

Choose quantities to make S = B = 1, invert (4), and multiply by the expected volume of sales to get total revenue

$$(5)\quad TR_t = P_t X_t = X_t^{\frac{\alpha-1}{\alpha}}\, \Pi_t^{\frac{\beta}{\alpha}} N_t^{\frac{\gamma}{\alpha}} D_t^{\frac{1-\gamma}{\alpha}}$$

The firm maximizes expected profits under the constraints that finished goods inventories change when output differs from sales, while material inventories change by the difference between materials bought and used.

$$(6)\quad \dot{N} = Y_t - X_t$$

$$(7)\quad \dot{M}_t = J_t - I_t$$

To solve the optimization problem we form the Hamiltonian, leaving out the time notation,

$$(8)\quad H = e^{-rt}\left\{X^{\frac{\alpha-1}{\alpha}}\,\Pi^{\frac{\beta}{\alpha}}N^{\frac{\gamma}{\alpha}}D^{\frac{1-\gamma}{\alpha}} - wL - mJ + \lambda_1\,[L^aI^bM^c - A(\dot{M}) - X] + \lambda_2(J - I)\right\}$$

The first-order conditions are

$$(9)\quad X:\quad \frac{\alpha-1}{\alpha}X^{\frac{-1}{\alpha}}\,\Pi^{\frac{\beta}{\alpha}}N^{\frac{\gamma}{\alpha}}D^{\frac{1-\gamma}{\alpha}} - \lambda_1 = 0$$

$$(10)\quad L:\quad -w + \lambda_1 a\ L^{a-1}I^bM^c = 0$$

$$(11)\quad J:\quad -m - \lambda_1 A'(\dot{M}) + \lambda_2 = 0$$

$$(12)\quad I:\quad \lambda_1[bL^aI^{b-1}M^c + A'(\dot{M})] - \lambda_2 = 0$$

The expected marginal revenue from sales must equal the shadow price of finished goods inventories. The firm must use labor up to the point where its marginal product, valued at the shadow price of finished goods inventories, equals the wage rate. Moreover, the firm must buy input materials at such a rate that the marginal cost, including the marginal adjustment cost of the stock of materials valued at the shadow price of finished goods, equals the shadow price of materials. Finally, the marginal product of material input, adjusted for the effect on the marginal adjustment cost implied by this input, valued at the shadow price of finished goods, also must equal the shadow price of material stocks.

Furthermore, we have

$$(13)\quad N:\quad r\lambda_1 - \frac{\gamma}{\alpha}X^{\frac{\alpha-1}{\alpha}}\,\Pi^{\frac{\beta}{\alpha}}N^{\frac{\gamma-\alpha}{\alpha}}D^{\frac{1-\gamma}{\alpha}} = \dot{\lambda}_1$$

$$(14)\quad M:\quad r\lambda_2 - \lambda_1 c\ L^aI^bM^{c-1} = \dot{\lambda}_2$$

$$(15)\quad \lambda_1:\quad L^aI^bM^c - A(\dot{M}) - X = \dot{N}$$

$$(16)\quad \lambda_2:\quad J - I = \dot{M}$$

The second term in (13) represents the marginal revenue of holding additional finished goods inventories. Integration of (13) shows that the finished goods shadow price is the present value of holding additional finished goods in stock. Similarly, (14) shows that the materials shadow price is the present value of the marginal product of holding additional material inputs, valued at the finished goods shadow price, in stock.

By eliminating the control variables from equations (13)–(16), we get the following differential equations. The rates of change of the shadow prices and stocks of finished goods and materials are

$$(17)\quad \dot{\lambda}_1 = r\lambda_1 - G_1\,\Pi^{\beta}N^{\gamma-1}D^{1-\gamma}\lambda_1^{1-\alpha}$$

$$(18)\quad \dot{\lambda}_2 = r\lambda_2 - G_2\,w^{-\frac{a}{c}}m^{-\frac{b}{c}}\lambda_1^{\frac{1}{c}}$$

$$(19)\quad \dot{N} = G_3\,w^{-\frac{a}{c}}m^{-\frac{b}{c}}\lambda_1^{\frac{a+b}{c}}M - A(\dot{M}) - G_4\,\Pi^{\beta}N^{\gamma}D^{1-\gamma}\lambda_1^{-\alpha}$$

$$(20)\quad \dot{M} = g\left[\frac{\lambda_2 - m}{\lambda_1}\right]$$

where $g(\ ) = A'^{-1}(\ )$ and sign $g(\ )$ = sign $A'(\ )$. It can be shown that $G_1 > 0$, $G_2 > 0$, $G_3 > 0$, and $G_4 > 0$. The parameters a, b, and c are from the production function while α, β, and γ are the own-price elasticity, the cross-price elasticity, and the inventory stock elasticity of sales.

The rate of change of the finished goods shadow price will depend on the demand variables while the rate of change of the materials shadow price depends on factor prices. The influence from demand comes indirectly via the finished goods shadow price.

Input costs, material stocks, and demand directly infuence the rate of change of the finished goods stock. The dampening effect of material adjustment costs is also apparent. The rate of change of material stocks depends positively on the difference between the shadow price and the market price of materials, and negatively on the finished goods shadow price.

In the long run, the stocks of finished goods and materials are at desired levels, given the expectations. These levels can be derived by setting $\dot{\lambda}_1 = \dot{\lambda}_2 = \dot{N} = \dot{M} = 0$ in the system of optimality conditions. Denoting the long-run desired levels of inventories and shadow prices by *, this yields

$$(21) \quad \lambda_1^* = G_2^{-c} r^c w^a m^{b+c}$$

$$(22) \quad \gamma_2^* = m$$

$$(23) \quad N^* = \Gamma_1 \Pi^{\frac{\beta}{1-\gamma}} w^{-\frac{a\alpha}{1-\gamma}} m^{-\frac{\alpha(1-a)}{1-\gamma}} r^{-\frac{1+c\alpha}{1-\gamma}} D$$

$$(24) \quad M^* = \Gamma_2 \Pi^{\frac{\beta}{1-\gamma}} w^{-\frac{a(\alpha+\gamma-1)}{1-\gamma}} m^{-\frac{a+\alpha-a\alpha-a\gamma}{1-\gamma}} r^{-\frac{1+c\alpha+c\gamma-c}{1-\gamma}} D$$

where $\Gamma_1 > 0$ and $\Gamma_2 > 0$. Equation (21) defines the long-run equilibrium shadow price of finished goods. It will vary positively with the factor prices and the interest rate. Equation (22) says that the shadow price of materials will equal the market price of materials in the long-run, since there are no adjustment costs for equilibrium stocks. Equation (23) and equation (24) say that the long-run equilibrium stocks are proportional to expected market demand. The constant returns to scale assumption is crucial for the result.

Both types of stocks vary positively with the competitors' average price levels. The wage rate and the market price of materials as well as the expected rate of interest affect long-run stocks negatively. Finished goods inventories are more interest elastic and also more sensitive to changes in the wage rate than material stocks. On the other hand, material inventories are more sensitive to material prices than finished goods stocks.

3. *Evidence*

Equation (23) and equation (24) in the previous section are the long-run structural relationships between inventory stocks and the explanatory variables of the theoretical model. We find the same set of explanatory variables in both equations. The parameters and the constants are functions of price and output elasticities. Still, we estimate the reduced form parameters in the subsequent analysis.

We test the logs of the variables for stationarity using the Sargan-Bhargava test (SB), the Dickey-Fuller test (DF), and the augmented Dickey-Fuller test (ADF). *Table 1* reports the results, which are consistent with the assumption that the levels are integrated of order one, i.e., the first differences are stationary. This can be questioned for the financial cost, the test statistics are close to the critical values. We have, nevertheless, proceeded on the assumption that all the levels are nonstationary while all the first differences are stationary.

Constant returns to scale implies that the two inventory stocks are proportional to the market demand, D, in the long run. In the cointegration regressions we have therefore used the logarithms of the ratios N*/D and M*/D as left hand side variables. *Table 2* presents the results of the cointegration regressions, which also include dummy variables for subsidies and seasonals. We interpret the test statistics in the table as consistent with the assumption that the regressions produce stationary linear combinations of the variables, i.e., that we have identified two cointegrating relationships.[8]

To check this conclusion we have used the likelihood ratio tests for cointegrating rank proposed by Johansen (1991). We find that there are at least two cointegrating relation-

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[8] *The DF-test residuals for finished goods seem nonwhite. When augmenting the test to obtain white noise residuals, however, the estimated lag coefficient is not significant. The ADF-statistic is significant at the 10 percent level while the DF-statistic is significant at the 5 percent level.*

Table 1. Integration tests.

	SB (DW-statistic)		DF (t-ratio)		ADF (t-ratio)	
	trend	no trend	trend	no trend	trend	no trend
logarithm of						
N	0.041	0.045	–0.46	–1.06	–2.01	–3.48*
M	0.143	0.143	–1.51	–1.51	–3.73*	–3.13
Π	0.057	0.087	–1.66	–0.70	–1.56	–1.27
w	0.036	0.088	–1.71	–1.85	–1.73	–2.14
m	0.062	0.086	–1.52	–0.75	–1.69	–1.23
r	0.637**	0.673**	–3.81*	–3.98*	–2.89	–3.04
D	0.012	0.346	–0.67	–2.96	–0.49	–2.49
difference of logarithm of						
N	0.952**	1.000**	–4.56**	–4.65**	–3.15	–3.33*
M	1.615**	1.627**	–6.69	–6.68**	–4.57**	–4.61**
Π	1.177**	1.226**	–5.80**	–5.88**	–5.17**	–5.24**
w	1.530**	1.543**	–6.90**	–6.89**	–4.84**	–4.84**
m	1.476**	1.562**	–6.73**	–6.85**	–5.09**	–5.22**
r	2.591**	2.593**	–11.95**	–11.88**	–7.66**	–7.61**
D	2.341**	2.345**	–10.50**	–10.44**	–3.22*	–3.18*

Notes: Constants and seasonals are included. ** significant at the 1 percent level, * significant at the 5 percent level. The sample periods are 1972: 1–1989: 4 (N and M) and 1969: 1–1989:4 (Π, w, m, r, and D), see the Appendix for further explanations. SB refers to Sargan & Bhargava (1983) who suggest that the Durbin-Watson statistic should be used to test for stationarity. Critical values are from Sargan & Bhargava (1983). DF and ADF refer to the Dickey-Fuller test and the augmented Dickey-Fuller test; see Dickey & Fuller (1979) and (1981). The t-ratios concern the null hypotheses that the variable is nonstationary. We choose the lag lengths of the ADF-tests to minimize the final prediction error, as defined by Akaike (1969a), (1969b).

Table 2. Cointegration regressions.

	relative stock of finished goods	materials
competitors' prices	2.59	0.69
labor costs	–1.02	–1.00
material prices	–1.29	–0.49
financial costs	–0.18	–0.06
investment subsidies	0.29	0.19
stock subsidies	0.52	0.23
R^2	0.62	0.76
SB(DW)	0.572*	0.500*
DF	–3.70*	–3.55*
Q(24), p-value	0.020	0.255
ADF	–2.86$^{(*)}$	
n of lags	1	
lag coefficient	not significant	
Q(24), p-value	0.106	

Notes: Constants and seasonals are included. * significant at the 5 percent level, $^{(*)}$ significant at the 10 percent level. Critical values for the Durbin-Watson statistic are from Sargan & Bhargava (1983). Critical values for the DF- and ADF-tests are from Engle & Granger (1987). The p-values for the Ljung-Box Q-statistics for autocorrelation of the residuals, using 24 autocorrelations, are reported in the row labeled Q(24). The null hypothesis is that the residuals are white noise. Investment subsidies is a dummy variable for 1972: 1–1972: 4 and 1975: 3–1976: 4. Stock subsidies is a dummy variable for 1977: 1–1977: 4.

ships among the variables. The trace statistic tests the null hypothesis against an additional relationship. *Table 3* shows that the null is clearly rejected for no relationship and for one relationship while we obtain a borderline rejection for two relationships. The null cannot be rejected for three relationships. The λ_{max} tests, which test the null against six relationships, point to two relationships. The null is rejected for no and one relationship while it cannot be rejected for two relationships.

All the estimated coefficients have the signs predicted by theory. Moreover, it turns out that all price and cost variables have higher weights in the realtionship with the relative finished goods stocks than in that with the relative materials stocks.

Figure 2 and *Figure 3* plot the cointegrating relationships. Positive values show that there are excess inventories, actual inventory stocks exceed the desired. The two time series share a strong cyclical pattern in the excess inventories, with an average length of the cycles of about five years, which seems highly (and negatively) correlated with the business cycle. Following the first oil crisis in 1974, there is a long period of excess inventory stocks. Two

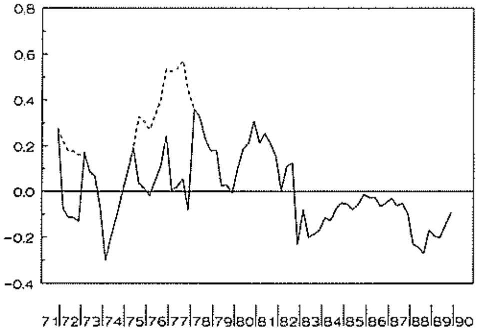

Figure 2. Excess finished goods inventories.

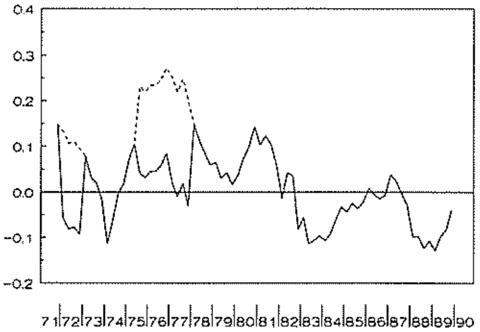

Figure 3. Excess materials inventories.

Table 3. Tests of the number of cointegrating relationships.

null hypothesis: number of relationships	trace	critical value 5 %	λ_{max}	critical value 5 %
0	129.1	82.8	47.7	35.7
1	81.4	59.9	38.8	29.7
2	42.6	40.8	22.0	24.0
3	20.5	25.5	14.7	18.1
4	5.9	13.2	5.4	11.9
5	0.5	3.9	0.5	3.9

Note: Critical values are from Jacobson & Larsson (1991).

large increases in 1978 and 1980 are also notable. The inventory subsidies were abolished in 1978, while the second increase coincides with the second oil crisis. Nevertheless, inventories were in excess, with short interruptions, until the 16 percent devaluation of the Swedish currency in 1982. After having returned to the long-run level in 1986, actual inventories have been lower than the long-run level during the last years of the 1980s.

The dotted lines show the excess inventories adjusted for the subsidies to inventory build-up in 1972 and in 1975–76 or to inventory maintenance in 1977.[9] Both plots show a substantial impact of the subsidies on the stocks. Note, however, that the figures suggest that there were excess inventories during 1975 and 1976 even when we control for inventory subsidies.

We will now use excess inventories from the cointegration regressions, lagged by one quarter, as explanatory variables (error correction terms) in estimations of inventory investment in finished goods and materials. We expect the impact of excess finished goods (material) inventories on finished goods (material) inventory investment to be negative, reflecting the wish of the firms to adjust their inventories toward the long run levels.

On the one hand, we expect the cross-effect of excess material stocks on investment in finished goods to be positive, since we expect firms to use their excess materials in production. On the other hand, we expect excess finished goods inventories to have a negative cross-effect on material investment, since firms are assumed to decrease the productive capacity when finished goods stocks are too large.[10]

In addition, we include differences in competitors' prices ($\Delta\Pi$), labor costs (Δw), material prices (Δm), the interest rate (Δr), and market demand (ΔD). We initially include contemporaneous values and four lags of these variables.[11] Moreover, the models also include lagged values of the inventory investment series. Finally, the models contain seasonal dummies and dummy variables representing inventory subsidies.

After the estimations of the full models, we proceed trying to find more parsimonious specifications. By successive tests we elimi-

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[9] *The estimated subsidy effects are excluded from the excess inventory series.*

[10] *The signs of the cross-effects follow from inventory investment equations derived in the theoretical model, see Gustafson (1991), Chapter 2.*

[11] *There are two reasons for the lag length choice. First, we are limited by the degrees of freedom, 68 observations and 41 coefficients leave us with 27 degrees of freedom. Each additional lag reduces the degrees of freedom by 8. Second, when using quarterly data, a lag length of 4 lies close at hand.*

Table 4. Error correction models.

	finished goods investment			materials investment		
	full	parsimonious model		full	parsimonious model	
	model	OLS	SUR	model	OLS	SUR
error correction terms:						
excess finished	–0.22	–0.23	–0.23	0.13	0.09	0.09
goods inventories	(2.03)	(3.85)	(3.81)	(1.61)	(2.36)	(2.35)
excess materials	0.43	0.46	0.45	–0.38	–0.26	–0.26
inventories	(1.65)	(3.44)	(3.41)	(2.00)	(2.94)	(2.91)
sums of lagged endogenous:						
finished goods	0.71	0.61	0.61	0.15	0.20	0.20
investment	(1.75)	(4.77)	(4.87)	(0.50)	(3.28)	(3.26)
material	–0.11	–0.45	–0.40	–0.04	–	–
investment	(0.15)	(2.22)	(2.07)	(0.07)		
sums of differences of other explanatory variables:						
competitors'	–0.53	–0.59	–0.56	0.35	–	–
prices	(0.72)	(1.56)	(1.57)	(0.65)		
labor costs	–0.56	–0.51	–0.51	0.52	0.16	0.16
	(0.82)	(2.69)	(2.77)	(1.03)	(1.09)	(1.14)
material prices	0.27	0.50	0.46	0.73	0.58	0.57
	(0.52)	(3.15)	(3.08)	(1.93)	(4.11)	(4.20)
financial costs	0.03	–0.01	–0.01	–0.00	–	–
	(0.65)	(1.46)	(1.64)	(0.11)		
market demand	0.89	1.20	1.15	–1.08	–0.47	–0.41
	(0.59)	(3.37)	(3.40)	(0.97)	(2.59)	(2.37)
dummies:						
investment	0.02	0.03	0.03	0.01	0.01	0.01
subsidies	(0.99)	(2.20)	(2.12)	(0.74)	(1.21)	(1.21)
stock	–0.01	–	–	–0.01	–	–
subsidies	(0.69)			(0.31)		
R^2	0.87	0.81	0.81	0.75	0.65	0.65
$\bar{R}^2$	0.67	0.75	0.75	0.38	0.58	0.58
SEE	0.025	0.022	0.022	0.018	0.015	0.015
DW	1.914	1.869	1.881	2.072	1.998	1.996
Q(24), p-value	0.49	0.73	0.69	0.58	0.89	0.88

Notes: Absolute t-values within parentheses. Constants and seasonals included. SEE refers to the standard error of the estimate. The null hypothesis of white noise residuals cannot be rejected for any estimation.

nate several variables. Besides the error correction terms, the investment subsidies, and the seasonals, we have chosen to keep the following variables:

In the model for finished goods inventory investment

$\Delta N_{t-1}, \Delta N_{t-2}$ ΔM_{t-3} $\Delta \Pi_t, \Delta \Pi_{t-3}, \Delta \Pi_{t-4}$ $\Delta w_{t-1}, \Delta w_{t-4}$
Δm_{t-3} Δr_{t-3} ΔD_{t-4}

and in the model for material inventory investment

ΔN_{t-1} $\Delta w_{t-2}, \Delta w_{t-4}$ $\Delta m_t, \Delta m_{t-2}$ ΔD_{t-2}.

Table 4 reports the results of the error correction estimations. The table gives the sums of the parameter estimates of all the lags for each variable and, in parentheses, the t-values of these sums. When the sets of regressors differ between equations there is a gain in efficiency from using the SUR (seemingly unrelated regression) estimation method instead of OLS (ordinary least squares) if the residuals are correlated across equations [Theil (1971), p 309]. Both methods have been used for the parsimonious models. Still, the results do not differ considerably.

The estimated coefficient of excess finished goods (excess materials) in the equation of finished goods (materials) has the expected negative sign and is clearly significant, particularly in the parsimonious models. The estimated adjustment speeds suggest that a gap between actual and desired inventories will be closed in about one year.

The impact of imbalances in the material stock on investment in finished goods inventories has the expected positive sign. Excess materials induce the firms to produce finished goods in excess of their sales. We also find that the absolute impact of excess material stocks is stronger than that of excess stocks of finished goods. This is contrary to the predictions of the theoretical model. The adjustment speed for materials is significantly estimated and slightly higher than that of finished goods.

The coefficient of excess finished goods in the material equation has been estimated to have a positive, although weak, impact on investment in material inventories. According to the theoretical model, the expected effect is negative, firms decrease not only production but the productive capacity when there are excess stocks of finished goods. If we assume that firms reduce their production when their finished goods stocks become larger than desired, our results suggest that material deliveries are slow to adjust. Material stocks, hence, tend to grow instead of to diminish when production slows down. The result is contrary to the predictions of the theoretical model.

The perhaps most striking single estimate is that for the inventory investment subsidy. We here obtain a significant and positive impact upon investment in finished goods. This implies that the subsidies contributed to keep unemployment down in the years following the first oil crisis.

The lagged changes of finished goods inventories are more powerful than those of material inventories in both equations. The lagged changes of materials are not even significant in the material investment equation. The change in the financial cost of holding inventories, including the financial impact of inventory subsidies, does not have a significant impact on inventory investment. Most empirical studies do not find a significant impact of financial costs.[12] An increase in the effective tax rate yields a rise in financial costs as we calculate them. We cannot, however, isolate the effects of taxes from those of the real interest rate. Finally, since the parameter estimates of the first differences of the other variables represent second derivatives of some inventory investment equations, it is difficult to have decisive expectations about the signs.

4. *Concluding remarks*

Our main findings can be summarized as follows:

1. Cointegration regressions, with variables from theoretical long run equations for inventory stocks, yield the predicted parameter signs. In particular, investment subsidies and stock subsidies are estimated to have increased optimal stocks.
2. Excess inventories yield significant coefficients in the inventory investment equations (error correction models). The estimations imply that a gap between actual and desired inventories will be closed in about one year.
3. Excess material inventories have the expected positive impact on finished goods inventory investment, while excess finished goods are estimated to have a positive, but small, impact on material inventory investment contrary to the expected negative sign. Our empirical results suggest that input deliveries are slow to adjust. Material stocks, therefore, tend to grow instead of to diminish when production slows down.
4. Investment subsidies have had a significantly positive effect on finished goods inventory investment, but not on material inventory investment.

Appendix: The data

The appendix gives the data sources and describes how we have calculated coherent time series. We have estimated on quarterly data for the manufacturing industry as a whole (ISIC 3). Inventory data are available for the

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[12] *See Gustafson (1991) for a brief survey.*

period 1972: 1–1989: 4. The other variables are available from 1969: 1. We use the longer data series in the integration tests.

Inventory stocks and investment – N, M

Statistics Sweden publishes quarterly inventory data in *Statistical Reports, Series I* (SM: I). We have used a special corrected print-out kindly supplied by Statistics Sweden to avoid misprints and calculation errors.

Competitors' prices – Π

We approximate the competitors' prices by the import price index for manufactured industrial products. It measures the prices of products imported to Sweden. Indirect taxes are not included. Monthly data for the period 1972: 4–1989: 4 have been recalculated to quarterly averages. Data are from the tables for the different ISIC-groups directly. For the period 1969: 1–1972: 3 there are no data for separate industries. The data for the import price index without branch specification are used. The data are linked using parallel series during 1972: 4–1973: 4. (Source: Statistics Sweden, SM:P.)

Labor costs – *w*

We use the monthly cost index for ISIC 3 blue collar workers; data for the mid month in each quarter are used. These data are available for the period 1974: 1–1989: 4. In the period 1969: 1–1973: 4 there are data for an older industry classification and collected from a different sample of firms. The index values for 1969: 1–1973: 4 have been calculated using the parallel 1974: 1–1976: 2 series for the absolute values. (Source: Statistics Sweden, SM:Am.)

Material prices – *m*

We approximate the materials price by an unpublished material price index kindly supplied by Statistics Sweden. The index summarizes the weighted average price of input materials, where certain »key goods» are used in each subsector. The index is given at the ISIC 3-, 4-, and 5-digit levels. We have aggregated it to ISIC 3 using »Costs of raw materials etc» published yearly in *SOS – Industry* as weight. The data are given monthly and have been recalculated into quarterly averages. Data are available from 1971: 1. Data for 1969: 1–1970: 4 are constructed assuming that the index = 100 in 1968: 3, and that the prices have increased linearly during that period.

Financial costs – *r*

The formula used is (Södersten & Lindberg (1983), pp 15–20):

$$r = \frac{(1 - f_2 T - f_3 g)R + pT(1 - f_2)}{1 - T} \qquad \text{(A1)}$$

where f_2 is the maximum tax deduction when investing in inventories, T is the total effective tax rate. The investment subsidy is represented by f_3g, where f_3 is the subsidized share of investment costs and g is the part of inventory investment eligible for subsidies. R is the real rate of interest and p is the inflation rate. $f_2 = 0.6$ for 1969–1983 and 0.5 from 1984 on, $g = 0.2$ and $f_3 = 1$ for 1972 and for 1975: 3–1976: 4, otherwise zero. Bergström & Södersten (1984) provide the series on T and R. Jan Södersten has kindly supplied data for the prolonged series. The inflation rate, p, is the rate of change of the quarterly averages of the producer price index (PPI) recalculated at a yearly basis. The index is a weighted average of prices of domestically produced products and the export price index. Indirect taxes are excluded. (Source: Statistics Sweden, SM:P.)

Market demand – D

For the market demand we have used GNP (West Germany and the US) or GDP (the UK, Finland, France, Denmark, and Norway) in fixed prices for Sweden's seven most important trading partners. For Denmark and Norway only yearly GDP-data are available. We assume that the index is the same all quarters within a year. (Source: OECD, *Quarterly National Accounts.*) The data for the different countries are weighted by each country's share of Sweden's export. (Source: Statistics Sweden, *Statistical Yearbook of Sweden.*)

Deflator

The relative prices of the competitors' goods, labor, and materials are calculated using the price index of domestic supply (ITPI) as deflator. The index measures the price of goods used within Sweden. It is computed as the weighted sum of PPI for home sales and the tariff corrected import price index. Monthly data are available from 1973. We use quarterly averages. ITPI is not available for 1969: 1–1972: 4. These observations are constructed from PPI, which are linked to the following data using the parallel 1973–1974 series. (Source: Statistics Sweden, SM:P.)

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