Why Don't Prices Fall in a Recession?

Financial Constraints, Investment, and Customer Relations*

12 February 2002

Charlotte Bucht[a], Nils Gottfries[b,c] and Magnus Lundin[b]

We construct a model of a financially constrained firm making pricing and investment decisions. The firm operates in a market where customers respond slowly to price changes and there are implementation lags in investment (time to build). Our model implies that the markup over marginal cost is counter-cyclical, the product price responds slowly to demand shocks, and quickly to cost shocks, and the price is strongly related to investment. Estimating the decision rules on aggregate data for Swedish industry, we find that the qualitative results are in line with our model.

Keywords: customer market, price rigidity, price equation, investment equation
JEL-codes: E31,E32,E44

* We are grateful for helpful comments from Jonas Agell, Marcus Asplund, Mikael Carlsson, Anders Forslund, and seminar audiences at the Bank of Sweden, Stockholm School of Economics, Stockholm University, and Uppsala University. We thank Mikael Carlsson for providing some of the data.

a) Ministry of Finance, Stockholm
b) Uppsala University
c) Corresponding author: Department of Economics, Uppsala University, Box 513, 751 20 Uppsala, Nils.Gottfries@econ.uu.se.

1. Introduction

The cyclical behavior of prices has re-emerged as an important focus of research in macroeconomics. The well-known failure of real business cycle models to fit price and wage data and the renewed interest in sticky-price models of monetary policy both highlight the importance of price adjustment. A better understanding of price adjustment is necessary in order to base business cycle theory and policy analysis on sound microeconomic foundations.

In classical economic models, prices move in such a way as to stabilize production and employment: if demand increases, firms raise prices, and this reduces demand. But the link between demand and prices, which follows immediately from standard microeconomic theory, has been hard to find in the data. Researchers who estimate conventional price equations typically find that prices do respond strongly and quickly to factor prices, but they are much less responsive to demand.[1] Bils and Chang (2000) confirm this result in a recent study. Shea (1993) found that prices in most industries do rise with demand, but with a considerable lag. Bils (1987) and Rotemberg-Woodford (1991, 1999) construct measures of marginal cost and conclude that the markup on marginal cost is strongly counter-cyclical.[2]

The cyclical pattern of the markup is important because a counter-cyclical markup will have a destabilizing effect on the economy, making the short-run supply curve flat and amplifying the effects of real demand disturbances. Also, as emphasized by Rotemberg and Woodford (1999), if an increase in demand has a negative effect on the *desired* markup, the resulting "real price rigidity" will amplify the effects of nominal frictions. Understanding real price rigidity is important in order to understand nominal price rigidity.[3]

The puzzling behavior of prices suggests that some important elements are missing in the textbook treatment of price determination. To understand price adjustment, we need to find these missing elements and develop richer and more realistic models of price dynamics. In this paper we argue that long-term customer relations, financial constraints, and

[1] For references to older literature, see e. g. Gottfries (1991) and Bils and Chang (2000).
[2] Closely related to this is the real wage puzzle: the real wage is not counter-cyclical, as predicted by Keynes, nor is it strongly procyclical, as implied by a typical real business cycle model. Note also that the nominal price level appears to be counter-cyclical in most countries (Danthine and Donaldson (1993)).
[3] See Romer (1996) for a thorough discussion of the interaction between real rigidity and nominal frictions in models with predetermined prices, adjustment costs etc.

interaction between pricing and investment are important determinants of cyclical price adjustment.

Several authors have pointed to the importance of long-term *customer relations*. Customers attracted by low prices tend to remain loyal and customers lost because of high prices are hard to win back. The seminal paper on "customer markets" by Phelps and Winter (1970) formalized the idea that firms face a choice between high prices and high profit margins today, and low prices, increasing market shares, and high profits in the future. Gottfries (1991) and Chevalier and Scharfstein (1996) showed that if firms in a customer market are *financially constrained*, markups may be counter-cyclical.[4] In a recession, companies may be forced to raise prices in order to maintain cash flows and pay their debts; in booms they can afford to pursue a more aggressive price policy. This points to financial variables as potentially important determinants of prices. Empirical evidence supporting this hypothesis can be found in Bhaskar, Machin and Reid (1993), Chevalier and Scharfstein (1996), Gottfries (2001) and Asplund, Eriksson and Strand (2001).

But if price decisions are dynamic because of customer relations, and firms are financially constrained, one would expect to see important interactions between pricing and investment decisions. High demand implies high cash flow, but also a need for additional capacity. Large predetermined investment expenditure, which must be financed, should make it more likely that firms become financially constrained. The purpose of this paper is to explore these interactions theoretically and empirically.[5]

We develop a dynamic model of a firm, which is financially constrained in the following sense. First, it is unable, or unwilling, to issue new shares. This may be because of adverse selection problems, because the owners fear loss of control, or for some other reason. Second, lenders are poorly informed and require collateral, so the firm can only borrow an amount corresponding to a fraction of its tangible assets. Third, managers or owners dislike fluctuations in dividends, and this we capture by assuming that the manager's objective is a concave function of dividends. Finally, we assume that it is sufficiently advantageous to borrow that the borrowing constraint is always binding.

The firm produces under constant returns to scale using capital and a flexible factor, and sells the goods in a "customer market". Customers tend to purchase from the same firm repeatedly and react slowly to price differentials. If a firm charges a price below the

[4] A large body of empirical work shows that financial variables, like cash flow, are correlated with investments, suggesting imperfections in the capital markets; see the survey by Hubbard (1998).
[5] The present paper builds on, and extends the analysis in Bucht (1997) in several directions.

average market price it gradually attracts new customers, and conversely. Hence the firm has two assets: physical production capital, and the customer stock (market share). The owner can invest in real capital - by conventional investment - and in the customer stock - by charging a low price to attract new customers.

To model investment it is important to allow for *time-to-build* - the fact that the completion of an investment project is a prolonged process. The importance of time-to-build has been stressed by e.g. Kydland and Prescott (1982). According to Nickell (1978), the whole completion process takes about 23 months, whereas Hall (1977) found evidence that investments are completed in 21 months. To capture this in a simple way, we assume that real capital investments must be decided one year in advance and that capital becomes productive one year after it has been installed.

We set up a dynamic optimization model with physical capital and the customer stock as state variables, solve it numerically and find optimal decision rules for price and investment. We then simulate the model and show that the model generates sluggish price adjustment after an unexpected permanent shock to demand. Because of time-to-build, investment is predetermined, so when demand falls, the firm finds itself in a financial squeeze. In order to finance investments and avoid drastic cuts in dividends, the firm will keep the price approximately unchanged. In subsequent periods, investment falls, and the firm becomes less financially constrained and cuts its price to increase its market share.

Four implications of the model are particularly noteworthy. First, there is a form of lagged price adjustment after the demand shock. Second, the markup over marginal cost is counter-cyclical. Third, and contrary to demand, a wage increase has an immediate effect on the price. Fourth, there is a strong effect of investment on the price because, high predetermined investment makes the firm more financially constrained.

To explore whether the aggregate dynamics of prices and investment are broadly consistent with the model, we estimate the decision rules for price and investment on aggregate data for the Swedish manufacturing industry 1960-1996. We find qualitative support for several of the predictions of the model, though the magnitudes of some coefficients differ from what we find in the simulations. The effect of investment on the price is particularly significant and quantitatively important.

In Section 2 we motivate our specification of the financial constraints. We set up the model in Section 3 and present the numerical solution in Section 4. The data and empirical results are presented in Section 5 and Section 6 shows some sensitivity analysis. Section 7 concludes.

2. Financial Constraints

Figure 1, shows the change in total assets, change in total (short and long-term) debt, new share issues, and dividends of Swedish manufacturing (SNI 3).[6] All variables are nominal accounting values relative to total assets in the previous year. We see that borrowing is closely correlated with the change in assets and that new share issues play a modest role. Dividends have increased over time, but they are much more stable than asset investment and borrowing. Neither share issues nor dividends seem to vary systematically with investment.

To introduce financial constraints in a way that is broadly consistent with these observations, we make four assumptions:

i) The firm does not issue shares. This may be because of adverse selection problems, because owners or managers fear loss of control, or for some other reason.[7]

ii) Potential lenders know very little about the earnings capacity of the firm and therefore require tangible assets as collateral in order to lend to the firm. We assume that borrowing can be used to finance a fixed fraction of the capital stock.

iii) Owners or managers dislike fluctuations in dividends. To capture this, we assume that the manager maximizes discounted present value of utility, where utility in one period is a concave function of dividends. In a small entrepreneurial firm, the owner/manager may have all his capital invested in the firm and live on the dividends, so his preference for smooth consumption translates into a preference for smooth dividends. More generally, it seems clear that firms dislike fluctuations in dividends, maybe because dividends are used to signal long-term profitability to shareholders.

iv) To make the financial constraints binding, we assume that the discount rate used to discount the utility of dividends is sufficiently high relative to the borrowing rate that the firm will always borrow as much as possible. This specification is made to highlight the role of financial constraints. The tax advantages of debt are an obvious reason why firms may find it advantageous to borrow as much as possible.

This specification of financial constraints is obviously very stylized. Effectively, the firm's capital structure is exogenously given. To explain the evolution of the capital

[6] This data is not used for the estimation below. Note that total assets include inventories and financial assets, which are omitted in the theory and the empirical analysis below.

[7] The adverse selection (lemons) problem arises if existing owners have inside information since they will tend to sell off shares exactly when the firm is overvalued in the stock market. Such adverse selection problems can lead to breakdown of the market for new shares.

structure is a very difficult task, however, which is beyond the scope of the present paper. Firms in our model do not have any financial assets. But if, realistically, the return on financial assets is lower than the borrowing rate, it cannot be rational to hold financial assets unless they yield some additional benefits. It would be straightforward to add a liquidity demand for financial assets in our model.[8]

Our assumptions imply that the borrowing constraint is always binding. In reality, we would expect some firms to be financially constrained, and some not. Also, firms may be financially constrained in bad times and unconstrained in good times.[9] This would make the analysis substantially more complicated, and weaken the results. The important implication of our specification is that, at any point in time, the shadow price of capital increases if investment is higher and decreases if profits increase.

3. The Model

The manager's objective is to maximize

$$\sum_{t=t}^{\infty} b^{t} \frac{D_t^{1-g}-1}{1-g}; \quad 0< b <1, g \geq 0, \tag{1}$$

where D_t is real dividends. The larger is g, the more the manager/owner dislikes fluctuations in dividends.[10] The firms' customer stock is X_t and each customer buys Y_t units, so production is

$$Q_t = X_t Y_t . \tag{2}$$

Because of imperfect information and/or switching costs, the customer stock changes slowly. It increases or decreases over time depending on the price charged by the firm, P_t relative to the average market price, P_t^0:[11]

[8] For example, we could assume that the return on financial assets is lower than the borrowing rate and that holdings of liquid assets are proportional to sales. In practice, there has been a strong trend increase in financial assets relative to total assets, probably due to the development of new financial instruments, formation of concerns, cross ownership etc.

[9] If a sufficiently good shock occurs in our model, firms will pay back debt and reduce borrowing below the maximum amount. Formally, we assume that such large good shocks do not occur.

$$\frac{X_t - X_{t-1}}{X_{t-1}} = -e\left(\frac{P_t - P_t^0}{P_t^0}\right) \quad . \tag{3}$$

Note that e is the within-period price elasticity, at the point where $P = P^0$. The production function takes the CES form in capital and a flexible production factor F:

$$Q_t = \left[(1-a)(A_t F_t)^r + aK_{t-1}^r\right]^{\frac{1}{r}} \quad ; \; 0 < a < 1. \tag{4}$$

Real dividends, D_t, are equal to revenue minus the cost of the flexible production factor minus the fraction of investment that is financed by retained earnings minus depreciation and interest payments, deflated by the relevant consumer price index, P_t^c:

$$D_t = \left[P_t Q_t - W_t F_t - (1-q)P_t^k (K_t - K_{t-1}) - P_t^k dK_{t-1}\right] / P_t^c - rqK_{t-1}, \tag{5}$$

where W_t is the price of the flexible factor, P_t^k is the price of capital goods, and q is the fraction of investment which is financed by borrowing. To simplify the model, we take the prices of consumption and capital goods to be equal to the market price, P_t^0. Using (2), (3) and (4) we may then write

$$D_t = \frac{1}{e}\left(1 + e - \frac{X_t}{X_{t-1}}\right) X_t Y_t - \left[\frac{1}{1-a}(X_t Y_t)^r - \frac{a}{1-a}K_{t-1}^r\right]^{\frac{1}{r}} \frac{W_t}{A_t P_t^0} - (1-q)(K_t - K_{t-1}) - dK_{t-1} - rqK_{t-1} \tag{6}$$

The relevant real rate of interest, r, is taken to be constant.

Time to build is captured by assuming that in period t, the capital stock is predetermined, and the firm decides about the capital stock in the coming period. The following Euler equations characterize the optimal plan in period t $(X_t, X_{t+1}, X_{t+2}, ..., K_{t+1}, K_{t+2}, K_{t+3}, ...)$:

[10] The real world is characterized by uncertainty, and uncertainty may affect decisions as in the case of precautionary saving. This we neglect: we assume that firms act *as if* they knew the future with certainty.
[11] For theoretical derivations of such an equation, see e. g. Phelps and Winter (1970), Gottfries (1986, 1991).

$$D_t^{-g}\left[\frac{1}{e}\left(1+e-2\frac{X_t}{X_{t-1}}\right)Y_t-\frac{X_t^{\,r-1}Y_t^{\,r}}{1-a}\left[\frac{1}{1-a}\left(X_tY_t\right)^r-\frac{a}{1-a}K_{t-1}^{r}\right]^{\frac{1-r}{r}}\frac{W_t}{A_tP_t^0}\right]+bD_{t+1}^{-g}\left(\frac{X_{t+1}}{X_t}\right)^2\frac{Y_{t+1}}{e}=0;$$

$$t=t,t+1,t+2\ldots \tag{7}$$

$$-(1-q)D_t^{-g}+bD_{t+1}^{-g}\left[\frac{aK_t^{\,r-1}}{1-a}\left[\frac{1}{1-a}\left(X_{t+1}Y_{t+1}\right)^r-\frac{a}{1-a}K_t^{\,r}\right]^{\frac{1-r}{r}}\frac{W_{t+1}}{A_{t+1}P_{t+1}^0}+1-q-d-qr\right]=0;$$

$$t=t+1,t+2,t+3\ldots \tag{8}$$

The first Euler equation (7) reflects the optimal choice of customer stock. The second term is positive because next period's profits increase if the firm comes into that period with a larger customer stock. Hence, the first term must always be negative in optimum; because customers are valuable, the price is always lower than the price that maximizes current profits. The second Euler equation (8) reflects the optimal investment plan for period t+1 onwards. On the margin, the fraction of investment expenditure, which is not debt-financed, is taken out of dividends, and this reduces utility in the period when the investment is carried out. Next period, the increase in the capital stock reduces costs, investment can be reduced, and the associated debt must be paid back with interest.

4. Numerical Solution of the Model

The model is too complicated to solve analytically so we solve it numerically. Because of constant returns to scale, we can write the Euler equations in terms of the ratios $Z_t = Q_t / K_t$ and K_t / K_{t-1} and the model has a steady state where these ratios are constant. We solve the model by log-linearizing the Euler equations around the steady state and picking the stable solution to the resulting system of linear difference equations. We assume that demand is expected to be constant and that if $W_t / A_t P_t^0$ deviates from its steady state value, it is expected to return gradually to the steady state value according to:

$$w_{t+1} - a_{t+1} - p_{t+1}^{0} = r_{w}\left(w_{t} - a_{t} - p_{t}^{0}\right); t = t, t+1, \ldots, \tag{9}$$

where $0 < r_{w} < 1$. Here and below lower case letters denote logs and constant terms are left out. In Appendix 1 we derive a closed-form log-linear solution for the optimal price in period t and planned investment in period t+1:

$$p_{t} - p_{t}^{0} = a_{pz}\ \left(q_{t-1} - k_{t-1}\right) + a_{pk}\ \Delta k_{t} + a_{pw}\ \left(w_{t} - a_{t} - p_{t}^{0}\right) + a_{py}\ \Delta y_{t}, \tag{10}$$

$$\Delta k_{t+1} = a_{kz}\ \left(q_{t-1} - k_{t-1}\right) + a_{kk}\ \Delta k_{t} + a_{kw}\ \left(w_{t} - a_{t} - p_{t}^{0}\right) + a_{ky}\ \Delta y_{t}, \tag{11}$$

where the coefficients are complicated functions of the underlying parameters in the model.

In our baseline simulation, we take the period to be one year, and we set the parameter values as follows:

$$r = 0, a = .19, e = .8, r = .04, b = .92, d = .08, q = .5, r_{w} = .7, g = 5. \tag{12}$$

Economic theory and other information suggest a plausible range for most of these parameters. The parameter ρ is set to zero so that the elasticity of substitution between the factors of production is one (Cobb-Douglas case), which is consistent with long run stability of the labor share. As usual, α should be equal to the capital share in total costs, which is 19 percent. The depreciation rate d is calculated assuming that the depreciation rate for machines is 12.3 percent and the depreciaiton rate for buildings is 3.6 percent, and that about half the capital stock consists of machines. The within-year price elasticity of demand ε, is calculated using estimates in Gottfries (2001). The real interest rate on debt is set to four percent and the owner is assumed to be more impatient, having a discount rate equal to 8 percent. One reason why the required return on equity is higher is the higher taxation of dividends relative to interest payments. The parameter θ is set to one half because, according to accounting data, *net* debt has been around 50 percent of the total real capital stock for

Swedish industry.[12] It is less clear what value we should chose for g , but in line with the observation that dividends are very smooth, we chose a relatively large value for γ.

The steady state value of $w_t - a_t - p_t^0$ determines whether the firm is growing or declining in the steady state. We set it in such a way that the firm is not growing in the steady state. With these parameter values, we get the following log-linear decision rules:

$$p_t - p_t^0 = 0.01\,(q_{t-1} - k_{t-1}) + 0.63\,\Delta k_t + 0.62\,(w_t - a_t - p_t^0) + 0.01\,\Delta y_t\,, \tag{13}$$

$$\Delta k_{t+1} = 0.37\,(q_{t-1} - k_{t-1}) - 0.57\,\Delta k_t - 0.17\,(w_t - a_t - p_t^0) + 0.37\,\Delta y_t \tag{14}$$

By construction, the coefficient on the lagged customer stock (market share) and the coefficient on the change in demand are equal in both equations; it does not matter for the firm whether it has more customers or each customer buys a larger quantity. In the price equation, this coefficient is small. The customer stock/demand has a very small effect on the price, while the effects of investment and costs are substantial. In the investment equation, the "accelerator effect" of demand is substantial, high investment in the previous period reduces the need to invest today, and higher wage costs have a small negative effect on investment.

Figure 2, panel A, illustrates the simulated effect of a 10 percent, unexpected permanent *decrease* in demand per customer. Initially, with investment predetermined, the firm finds itself in a financial squeeze. To finance predetermined investments, and avoid drastic cuts in dividends the price is kept approximately unchanged. In the subsequent period, investment is reduced, and the firm is less financially constrained, so it can afford to cut its price to increase the market share. Thus, the price does not fall immediately, but there is a form of lagged price adjustment after the demand shock. An important implication of the model is that high investment makes the firm more financially constrained, so it sets a higher price. Panel B shows the effect of a demand shock using estimated decision rules; these are discussed in the next section.

Panel C shows the effect of the demand shock on the markup. Since output increases, the short run marginal cost curve is upward sloping, and the price initially does not change much, the markup on marginal cost increases substantially in the recession.

[12] Net debt is calculated as all debt minus financial assets, excluding shares in related companies. Here, capital includes machines, buildings and inventories. Source: Företagen, SCB.

In Figure 3 we illustrate the effect of a 10 percent *increase* in the price of the flexible factor. As discussed above, the shock is assumed to be persistent but not permanent. Contrary to the case of a demand shock, the effect is immediate, and the price moves more or less in line with the input price, but with less than full "pass-through" of costs into prices. [13] The predicted response to a cost shock is similar to what we get in a static model. The effect on investment is relatively small. To understand this, note that higher wage cost means higher prices and lower sales, but also substitution away from labor to capital; the net result is a small negative effect on investment.

The financial constraints are very important for these results. To illustrate this, consider the case of an owner who has perfect access to the credit market and therefore no desire for smooth dividends. Setting g close to zero and keeping the other parameters constant we get the price and investment policy that maximizes the present value of dividends. This policy is shown in Column 2 of Table 1, and the effect of a permanent demand shock is illustrated in Figure 4. In this case, a demand shock has an immediate and large positive effect on the price - as in a static model. Furthermore, there is no longer any positive relation between investment and prices.

Another interesting issue concerns the slope of the short run marginal cost curve. One may argue that a Cobb-Douglas production function, with a unit elasticity of substitution between capital and labor, implies an implausibly large short-run substitutability, and hence a too flat marginal cost curve when the capital stock is predetermined.[14] To examine the effect of lower substitutability we set $r = -1$, implying an elasticity of substitution equal to one half. As we see from Column 3, the solutions for the optimal price and investment are similar to the baseline case. Although the short-run marginal cost curve is steeper, the effect of demand on the price is still very small. The contercyclical markup dominates even if we increase the slope of the marginal cost curve. The most important difference is that demand now has a stronger effect on subsequent investment because it is more important for the firm to have the right factor mix. Also, investment now has a smaller effect on the price. High future capacity makes it more desirable to attract customers – mitigating the effect of the financial constraint.

Experiments with alternative values for the other parameters show that the qualitative results that we found in the baseline case are quite robust (Table 2, columns 4-6).

[13] So far, we have not allowed for predetermined prices.

[14] On the other hand, one may argue that less than full utilization of factors has the opposite effect – see Rotemberg and Woodford (1999) for a thorough discussion of this.

To sum up, financial constraints do affect the solution in a significant way, but the qualitative implications of the model are robust with respect to modest changes in the other parameters.

The decision rules were derived assuming that the financial constraint always binds. As long as the constraint binds, behavior will be symmetric for negative and positive shocks. But a sufficiently large positive demand shock can put the firm in a position where it finds it more advantageous to save financially than to cut the price further to compete for market shares. In such a situation it will pay off debt and borrow less than the feasible amount. For the parameter values used in the baseline simulation this occurs if the unexpected positive demand shock is larger than 25 percent.[15]

5. Estimates of Decision Rules for Swedish Manufacturing Industry

In order to see whether the model can capture the broad features of aggregate time series data, we estimate the price equation and the investment equation on yearly data for the Swedish manufacturing industry 1960-1996. We use yearly data because quarterly data is not available for the 1960s and because a one-year implementation lag for investment is plausible and incorporating time to build in a quarterly model would be much more complicated. Our output measure is gross output and the price is the producer price index. The capital stock is computed from investment data by the perpetual inventory method. Factor productivity is calculated by the Solow method. A detailed description of the data is found in Appendix 2.

We think of the behavioral equations as applying to the representative Swedish firm. When going from the representative firm to the aggregate level we have to take account of two problems. First, Swedish firms sell their products in both foreign and domestic markets, and the representative Swedish firm competes with other Swedish firms, particularly in the domestic market. Second, a large fraction of costs are costs of intermediate goods produced by other Swedish firms. Therefore, the market price, p_t^0, and the relevant cost index, w_t, both consist to a considerable extent of Swedish prices, i. e. one of the dependent variables.[16] Formally, this serious simultaneity problem can be dealt with by appropriate choice of instruments, but since we do not have very much data, we chose not to rely on asymptotic properties more than necessary. We therefore solve the model for the price as a function of relatively exogenous variables. To do this, we assume that the firm sets the same

[15] Clearly, the size of the required shock depends on the difference in the required return between debt and equity.

[16] This problem is emphasized by Basu (2000).

price in all markets, i. e. we ignore pricing to market,[17] and we define the (average market) price as:

$$p_t^0 = s\left((1-v)p_t + vp_t^i\right) + (1-s)p_t^f \ , \tag{16}$$

where s is the share of output going to the domestic market in 1980, v is the share of imports in domestic "apparent consumption" (production plus imports minus exports) in 1980, p_t^i is the import price, and p_t^f is a competition-weighted sum of foreign producer prices. Further, we assume that the flexible factor F is a Cobb-Douglas aggregate of labor L, imported inputs I, and domestic inputs M:

$$F_t = L_t^{1-l_1-l_2} I_t^{l_1} M_t^{l_2} \ . \tag{17}$$

Denoting the wage cost per hour w_t^ℓ, taking the price of domestic inputs to be the same as the output price, and the price of imported inputs to be the import price, p_t^i, we can write the relevant cost index as

$$w_t = (1 - l_1 - l_2)w_t^\ell + l_1 p_t^i - l_2 p_t \, , \tag{18}$$

where the weights are equal to the cost shares. Substituting (16) and (18) into the price equation (10), we can solve for the price relative to the foreign price level:

$$p_t - p_t^f = \frac{1}{1 - a_{pw} l_2 - (1 - a_{pw})(1 - v)s} \times$$

$$\left[a_{pz} \ (q_{t-1} - k_{t-1}) + a_{pk} \ \Delta k_t + a_{pw}(1 - l_1 - l_2)(w_t - p_t^f) + \left(a_{pw} l_1 + (1 - a_{pw})sv\right)(p_t^i - p_t^f) - a_{pw} a_t + a_{py} \ \Delta y_t \right] \tag{19}$$

[17] Allowing explicitly for two markets, we would have both market shares as state variables. While interesting, such an extension is beyond the scope of this paper.

Setting the weights l_1, l_2 equal to the cost shares, calculated from the input-output matrix, we can recover the parameters in the original price equation by nonlinear estimation of equation (19).

The demand index, y_t, is constructed analogously as a weighted sum of foreign and domestic demand indices:

$$y_t = sy_t^d + (1-s)y_t^f, \tag{15}$$

where y_t^d is domestic "gross apparent consumption" (gross production plus imports minus exports), and y_t^f is a trade-weighted index of foreign market demand (industrial production).

The investment equation was estimated as it stands, using the instruments listed below. We included trend and trend squared in the equations to pick up missing trend factors, such as changes in product mix, emergence of new competition, unobserved costs etc. There are good reasons to expect some serial correlation in the errors. First, the omitted shocks may themselves be serially correlated. Second, measurement errors and predetermined prices will lead to a moving average structure in the errors.[18] We therefore estimate the equations by GMM allowing for first order moving average errors. In the baseline specification we use the following instruments: $w_t^\ell - p_t^f, a_t, \Delta y_t, z_{t-2}, \Delta k_{t-1}, w_{t-1}^\ell - p_{t-1}^f, a_{t-1}, \Delta y_{t-1}$ constant, trend, and trend squared.

The data is illustrated in Figures 5-7. Figure 5 shows the factor price and the output price relative to the market price. The factor price appears to be an important determinant of the relative price, but the price varies less than the factor price relative to the foreign price; firms take account of foreign competitors' prices when they set prices. The diagram also shows investment, and we see that periods of high investment appear to be associated with high prices. Figure 6 shows that output movements are primarily driven by demand, though we also see some loss of market share in periods when costs were high (1975-76 and late 1980s) and gains of market shares after the currency had depreciated in 1982 and 1992.[19] Figure 7 illustrates the "accelerator effect" on investment; we note a lag of about one-year between peaks in output and peaks in investment.

[18] An i. i. d. measurement error for Y_t, for example, will imply that the measurement error for its growth rate is a moving average error of the first order.
[19] See Gottfries (2001) for a closer analysis of relative prices and market shares for exports.

The results of estimation are reported in Table 2. For comparison, we report the simulated coefficients for the baseline case in Column 1. Our purpose here is not to make a formal statistical test of the model, but to see whether the qualitative predictions of the model are confirmed. In fact, most qualitative results are in line with the predictions of the model. In the price equation, costs and investment have very significant effects of the expected magnitude. The coefficients for the demand variables are small and not significantly different from zero. In the investment equation, the accelerator effect of demand variables is very clear, though somewhat smaller than the model predicts. One reason may be that we have neglected adjustment costs in the theoretical model. Costs have the expected negative effect on investment. The main failure is that we cannot replicate the negative effect of lagged investment on current investment. Again, this may be due to our negligence of adjustment costs, or because of omitted variables that affect investment and which are themselves serially correlated.

The similarity between the theoretical and the estimated model is illustrated in panels 1B and 2B, showing the effects of shocks with estimated decision rules. The sluggish price response to the demand shock and a close correlation between investment and price is evident in both cases.

6. Sensitivity of Estimates

In Table 2 we report some alternative estimates to check the sensitivity of our results with respect to changes in the specification. These alternative estimates address the following concerns: predetermined prices, variations in factor utilization, reverse causality between investment and prices, and alternative specification of the trend.

Predetermined prices: So far we have disregarded predetermined prices. We did this to keep the model clean and avoid confusing the mechanisms discussed here with conventional nominal price rigidity. However, there are several reasons to allow for prices being set in advance. First, there is considerable survey evidence that prices are changed infrequently and a correctly specified econometric model should take account of this.[20] Second, predetermined prices is an alternative, or complementary, explanation of counter-cyclical markups. If monopolistic firms adjust their prices infrequently, an unexpected negative demand shock will imply unexpectedly low production, low marginal cost, and high

[20] According to Assarsson (1989) and Blinder et al (1998), the frequency of price adjustments is typically once or twice per year.

markup. [21] Third, one may suspect that the statistical correlation between investment and prices arises because both variables respond slowly to demand shocks. If both the capital stock and the price are chosen one period in advance, a simultaneous decrease in the price and the capital stock may just reflect decreasing demand in the previous period.[22]

One way to allow for predetermined prices is to assume that firms try to implement the decision rules above, but they have to set prices for period t based on information available in period t-1. Under rational expectations, we may then estimate the decision rules using only lagged variables as instruments. In *Table 2 column 3,* we show the result when $w_t^\ell - p_t^f, a_t, \Delta y_t$ are replaced by $w_{t-2}^\ell - p_{t-2}^f, a_{t-2}, \Delta y_{t-2}$ in the list of instruments. The results are qualitatively similar to the baseline specification.

A more direct way to test whether the correlation between investment and prices arises because both react with a lag to demand is to simply add a lagged demand variable on the right hand side of the price equation (and use the original set of instruments). If the correlation between investment and price is spurious for the reason explained above, we would expect lagged demand to come in significantly, and the effect of investment on the price to disappear. As we see in *Table 2, column 4*, lagged demand does not have a significant effect on the price, and the effect of investment on the price remains large.

Factor utilization: We have used total factor productivity (the Solow residual) as measure of technology changes. The Solow residual is clearly procyclical and there is considerable evidence that this is partly due to variations in factor utilization.[23] One way to eliminate this measurement error from our technology measure is to use a smoothed measure of factor productivity instead of actual factor productivity. We do this in a simple way by regressing factor productivity on a constant, trend, trend squared and cubic trend, and using the fitted values instead of a_t.[24] As can be seen in *Table 2*, *column 5,* the coefficients for the demand variables become even smaller, and this is to be expected since our measure of a_t is less procyclical in this case. The difference is small, however.

Reverse causality: In our baseline specification we found a strong contemporaneous relation between investment and prices. Under the maintained hypothesis that it takes time to build, so investment is predetermined, we interpreted this as a causal

[21] We assume here that markups are sufficiently high that firms always want to satisfy demand ex post.
[22] Note, however, that in such a model, a positive cost shock would imply higher cost and lower investment in the subsequent period.
[23] See e. g. Burnside, Eichenbaum and Rebelo (1995) and Basu and Kimball (1997) for U. S. evidence and Carlsson (2000) for Swedish evidence.

effect of investment on prices. A potential objection is that this statistical relation may be due to reverse causality. If, for some unknown reason, firms are able to charge higher prices, profitability increases, and there is stronger incentive to invest. Thus, high prices may cause high investment rather than the reverse.[25] Note, however, that if the causality were indeed the reverse, then with time-to-build, we would expect investment in period t+1 to depend on the price in period t.[26] In order to check this, we included the relative price in the investment equation (also adding it as instrument). As seen in *Table 2, column 6*, the coefficient for the lagged relative price comes out with a negative value. This is strong evidence against the reverse causality interpretation of our results.

Stochastic trend: Adding deterministic trends may lead to spurious results if the trends are stochastic. We therefore estimated the model after taking first differences on both sides of the equations and leaving out the quadratic trend term.[27] The instruments were differenced accordingly. The result is shown in *Table 2, column 7.* Again, the results are qualitatively similar to the baseline (level) specification.

7. Conclusion

The present paper started off from two well-documented facts. The first is that the market position is an important asset of a typical firm and a relatively high price leads to erosion of the market position. Therefore, firms should care about the long-term consequences of their pricing decisions. The second is that financial markets are not perfect. Owners often have limited resources. New equity finance is associated with information problems and loss of control and plays a modest role in practice. Borrowing is restricted because few firms have access to bond markets, and lenders often require collateral for their borrowing. Consequently, it is generally accepted that financial factors matter for investment.

But if pricing decisions are effectively dynamic investment decisions and financial markets are imperfect, two conclusions are inescapable. First, financial constraints should affect pricing decisions and, second, there should be important interactions between physical investment in production capital and price competition for market shares. On the one

[24] This approach may produce a better measure of technology if technology is a smooth process, but this is not necessarily the case. Also, it does not address the question *why* there are variations in factor utilization.
[25] An example is serially correlated measurement errors in p_t^*. An unobserved increase in the true p_t^* may cause both price and investment to rise.
[26] As noted in the introduction, there is considerable evidence that there are implementation lags in investment.
[27] Thus, variables which are already appear in first differenced form in the decision rules now appear as second order differences.

hand, the two stocks are complements: a higher capacity is more valuable if one has a high market share, and conversely. On the other hand, they compete for available financial resources at a given point in time; charging a low price, to penetrate the market, is costly, and so is physical investment.

We have shown that a model that allows for these realistic features can explain several of the puzzles relating to price dynamics. Prices are found to respond slowly to demand shocks, but immediately to cost shocks, and the markup is strongly counter-cyclical. An implication of the model is that price should depend strongly on investment, and we find very strong evidence of this when we estimate the model on time series data for Swedish manufacturing.

References

Asplund, Marcus, Rickard Eriksson and Niklas Strand, 2001, Prices, Margins, and Liquidity Constraints: Swedish Newspapers 1990-1996, mimeo, Stockholm School of Economics.

Assarsson, Bengt, 1989, *Prisbildning på industriella marknader.* Stockholm: SNS.

Basu, Susanto, 2000, Understanding how Price Responds to Costs and Production – A Comment, *Carnegie- Rochester Conference Series on Public Policy* 52, 79-85.

Basu, S. and Fernald, J., 1997, Returns to scale in U.S. production: estimates and implications, *Journal of Political Economy* 105, 249-283.

Basu, S. and M. Kimball, 1997, Cyclical productivity with Unobserved Input Variation, NBER working paper 5915.

Bhaskar, V., S. Machin and G. C. Reid, 1993, Price and quantity adjustment over the business cycle: evidence from survey data, *Oxford Economic Papers* 45, 257-268.

Bils, Mark (1987): "The Cyclical Behavior of Marginal Cost and Price", *American Economic Review*, December 1987, 77(5), pp. 838-855.

Bils, Mark, and Yongsung Chang, 2001, Understanding how price responds to costs and production, *Carnegie-Rochester Conference Series on Public Policy* 52, 33-77

Blanchard, O. J. and Angelo Melino, 1986, The cyclical behavior of prices and quantities, *Journal of Monetary Economics* 17, 379-407.

Blinder, A. S., E. D. Canetti, D. E. Lebow, and J. B. Rudd, 1998, *Asking about prices - a new approach to understanding price stickiness*, Russel Sage; New York.

Bucht, Charlotte (1997): "Interaction Between Price Setting and Capital Investment in a Customer Market", Uppsala university, 1997, Working paper 1997:27, Department of Economics

Burnside, C., Eichenbaum, M., and Rebelo, S., 1995, Capital utilization and returns to scale, in NBER *Macroeconomics Annual 1995*, 67-110.

Calmfors, L. and J. Herin, 1979, Domestic and foreign price influences - a disaggregated study of Sweden, in Lindbeck (ed.) *Inflation and Employment in Open Economies*, North-Holland, Amsterdam.

Carlsson, Mikael, 2000, Measures of technology and the short-run responses to technology shocks, working paper 2000:20, Department of Economics, Uppsala University.

Chevalier, J. A and D.S. Scharfstein, 1996, Capital market imperfections and countercyclical markups: theory and evidence, *American Economic Review* 86, 703-725.

Danthine, J. P. And J. Donaldson, 1993, Methodological and empirical issues in real business cycle theory, *European Economic Review* 37, 1-35.

Froot, K. A. and P. D. Klemperer, 1989, Exchange rate pass-through when market share matters, *American Economic Review* 79, 637-654.9

Gottfries, Nils, 1986, Price dynamics of exporting and import-competing firms, Scandinavian *Journal of Economics* 88, 417-436.

- " - , 1991, "Customer Markets, Credit Market Imperfection and Real Price Rigidity", *Economica*, 58, August 1991, pp. 317-323

- " -, 2001, "Market Shares, Financial Constraints, and Pricing Behavior in the Export Market", forthcoming in *Economica*.

Hall, Robert, 1977, Investment, Interest Rates and the Effects of Stabilization Policy; *Brookings Papers on Economic Activity* 1977:1, 61-103.

Hubbard, R. Glenn, 1998, Capital-Market Imperfections and Investment, *Journal of EconomicLiterature* 36, 193-225.

Klemperer, P., 1987, Markets with consumer switching costs, *Quarterly Journal of Economics* 102, 375-394.

Klemperer, P., 1995, Competition when consumers have switching costs - an overview with applications to industrial organization, macroeconomics, and international trade, *Review of Economic Studies* 62, 515-539.

Kydland, Finn E. and Edward Prescott, 1982, Time to Build and Aggregate Fluctuations, Econometrica 50, 1345-1370.

Nickell, Stephen J., 1978, *The Investment Decisions of Firms*, Cambridge University Press.

Phelps, Edmund S. and Sidney G. Winter, 1970, Optimal price policy under atomistic competition, in Phelps, E.S. (ed.): *Microeconomic Foundations of Employment and Inflation Theory*, Norton New York.

Romer, David, 1996, *Advanced Macroeconomics*, (McGraw-Hill, New York).

Rotemberg, J.J. and M. Woodford, 1991, Markups and the business cycle, NBER *Macroeconomics Annual 1991* (MIT Press, Boston), 63-140.

- " -, 1995, Dynamic general equilibrium models with imperfectly competitive product markets, in Cooley, T. (ed), *Frontiers of Business cycle research*, Princeton Unicersity Press, New Jersey.

- " -, 1999, The cyclical behavior of prices and costs, Chapter 16 in Taylor and Woodford (ed.), *Handbook of Macroeconomics*, North Holland Elsevier, Amsterdam.

Sargent, T.J., 1979, *Macroeconomic theory* (Academic press, New York).

Shea, John, 1993, Do Supply Curves Slope Up? *Quarterly Journal of Economics* 108, 1-32.

Appendix 1: Derivation of the closed-form solution

Multiplying the first Euler equation by K_{t-1}^{g}/Y_t we may write it in terms of the ratios $X_tY_t/K_t, K_t/K_{t-1}, Y_t/Y_{t-1},$ and $W_t/(A_tP_t^0)$:

$$\left(\frac{D_t}{K_{t-1}}\right)^{-g}\left[\frac{1+e}{e}-\frac{2}{e}\frac{X_tY_t}{K_t}\frac{K_{t-1}}{X_{t-1}Y_{t-1}}\frac{K_t}{K_{t-1}}\frac{Y_{t-1}}{Y_t}-\frac{1}{1-a}\left(\frac{1}{1-a}-\frac{a}{1-a}\left(\frac{K_t}{X_tY_t}\frac{K_{t-1}}{K_t}\right)^{r}\right)^{\frac{1-r}{r}}\frac{W_t}{A_tP_t^0}\right]$$
$$+\frac{b}{e}\left(\frac{D_{t+1}}{K_t}\right)^{-g}\left(\frac{K_t}{K_{t-1}}\right)^{-g}\left(\frac{X_{t+1}Y_{t+1}}{K_{t+1}}\frac{K_t}{X_tY_t}\frac{K_{t+1}}{K_t}\frac{Y_t}{Y_{t+1}}\right)^{2}\frac{Y_{t+1}}{Y_t}=0.$$

(A1)

Multiplying the second Euler equation by K_{t-1}^{g} we get

$$-(1-q)\left(\frac{D_t}{K_{t-1}}\right)^{-g}+$$
$$b\left(\frac{D_{t+1}}{K_t}\right)^{-g}\left(\frac{K_t}{K_{t-1}}\right)^{-g}\left[\frac{a}{1-a}\left(\frac{1}{1-a}\left(\frac{X_{t+1}Y_{t+1}}{K_{t+1}}\frac{K_{t+1}}{K_t}\right)^{r}-\frac{a}{1-a}\right)^{\frac{1-r}{r}}\frac{W_{t+1}}{A_{t+1}P_{t+1}^0}+1-q-d-qr\right]=0$$

(A2)

where

$$\frac{D_t}{K_{t-1}}=\frac{1}{e}\left(1+e-\frac{X_tY_t}{K_t}\frac{K_{t-1}}{X_{t-1}Y_{t-1}}\frac{K_t}{K_{t-1}}\frac{Y_{t-1}}{Y_t}\right)\frac{X_tY_t}{K_t}\frac{K_t}{K_{t-1}}-\left(\frac{1}{1-a}\left(\frac{X_tY_t}{K_t}\frac{K_t}{K_{t-1}}\right)^{r}-\frac{a}{1-a}\right)^{\frac{1}{r}}\frac{W_t}{A_tP_t^0}$$
$$-(1-q)\left(\frac{K_t}{K_{t-1}}-1\right)-d-rq$$

(A3)

Define $z_t=\ln(X_tY_t/K_t), \Delta k_t=\ln(K_t/K_{t-1}),\ \Delta y_t=\ln(Y_t/Y_{t-1})$ and $\hat{w}_t=\ln(W_t/(A_tP_t^0))$. We may now write the Euler equations:

$$f\left(z_{t+1}, z_t, z_{t-1}, \Delta k_{t+1}, \Delta k_t, \hat{w}_{t+1}, \hat{w}_t, \Delta y_{t+1}, \Delta y_t\right) \equiv$$

$$\left(\frac{D_t}{K_{t-1}}\right)^{-g}\left[\frac{1}{e}\left(1+e-2e^{z_t - z_{t-1} + \Delta k_t - \Delta y_t}\right) - \frac{1}{1-a}\left(\frac{1}{1-a} - \frac{a}{1-a} e^{-r(z_t + \Delta k_t)}\right)^{\frac{1-r}{r}} e^{\hat{w}_t}\right] \tag{A4}$$

$$+\frac{b}{e}\left(\frac{D_{t+1}}{K_t}\right)^{-g} e^{-g\Delta k_t + 2(z_{t+1} - z_t + \Delta k_{t+1}) - \Delta y_{t+1}} = 0$$

$$g\left(z_{t+1}, z_t, z_{t-1}, \Delta k_{t+1}, \Delta k_t, \hat{w}_{t+1}, \hat{w}_t, \Delta y_{t+1}, \Delta y_t\right) \equiv -(1-q)\left(\frac{D_t}{K_{t-1}}\right)^{-g}$$
$$+ b\left(\frac{D_{t+1}}{K_t}\right)^{-g} e^{-g\Delta k_t}\left[\frac{a}{1-a}\left(\frac{e^{r(z_{t+1} + \Delta k_{t+1})}}{1-a} - \frac{a}{1-a}\right)^{\frac{1-r}{r}} e^{\hat{w}_{t+1}} + 1 - q - d - qr\right] = 0 \tag{A5}$$

where

$$\frac{D_t}{K_{t-1}} = \frac{1}{e}\left(1+e-e^{z_t - z_{t-1} + \Delta k_t - \Delta y_t}\right)e^{(z_t + \Delta k_t)} - \left(\frac{e^{r(z_t + \Delta k_t)}}{1-a} - \frac{a}{1-a}\right)^{\frac{1}{r}} e^{\hat{w}_t} - (1-q)\left(e^{\Delta k_t} - 1\right) - d - rq\,.$$
(A6)

Labor cost determines whether the firm shrinks or grows in steady state. We choose the steady state value of $\hat{W}$ so that the firm neither grows nor shrinks in steady state $(\Delta k = 0)$. Linearizing around the stationary solution and leaving out the constant term we get:

$$0 = f\left(z_{t+1}, z_t, z_{t-1}, \Delta k_{t+1}, \Delta k_t, \hat{w}_{t+1}, \hat{w}_t, \Delta y_{t+1}, \Delta y_t\right) \approx$$
$$\left(f_1 + f_2 L + f_3 L^2\right) z_{t+1} + \left(f_4 + f_5 L\right)\Delta k_{t+1} + \left(f_6 + f_7 L\right)\hat{w}_{t+1} + \left(f_8 + f_9 L\right)\Delta y_{t+1} \tag{A7}$$

$$0 = g\left(z_{t+1}, z_t, z_{t-1}, \Delta k_{t+1}, \Delta k_t, \hat{w}_{t+1}, \hat{w}_t, \Delta y_{t+1}, \Delta y_t\right) \approx$$
$$\left(g_1 + g_2 L + g_3 L^2\right) z_{t+1} + \left(g_4 + g_5 L\right)\Delta k_{t+1} + \left(g_6 + g_7 L\right)\hat{w}_{t+1} + (g_8 + g_9 L)\Delta y_{t+1} \tag{A8}$$

where L is the lag operator and the coefficients are the derivatives of *a* and *b* evaluated at the steady state. We assume that shocks to demand are perceived as permanent while cost shocks are expected to be reversed in the future:

$$\begin{aligned}&\Delta y_t = 0, t = t+1, t+2, t+3, \ldots \\ &\hat{w}_t = f\hat{w}_{t-1}; 0 < f < 1, t = t+1, t+2, \ldots\end{aligned} \qquad \text{(A9)}$$

Consider now periods $t = t+1, t+2, \ldots$ for which $\Delta y_t = 0$. Multiply (A7) by $(g_4 + g_5 L)$ and (A8) by $(f_4 + f_5 L)$ and eliminate the terms involving Δk :

$$\begin{aligned}&\left[\left(f_1 + f_2 L + f_3 L^2\right)(g_4 + g_5 L) - (f_4 + f_5 L)\left(g_1 + g_2 L + g_3 L^2\right)\right] z_{t+1} \\ &= \left[(f_4 + f_5 L)(g_6 + g_7 L) - (f_6 + f_7 L)(g_4 + g_5 L)\right]\hat{w}_{t+1}\end{aligned} \qquad \text{(A10)}$$

Using (A9) and collecting terms in the polynomial on the left hand side we can write:

$$\left(A + BL + CL^2 + DL^3\right) z_{t+1} = H\hat{w}_{t-1}\,, \qquad \text{(A11)}$$

where

$$A = f_1 g_4 - f_4 g_1 \qquad B = f_1 g_5 + f_2 g_4 - f_5 g_1 - f_4 g_2$$

$$C = f_2 g_5 + f_3 g_4 - f_5 g_2 - f_4 g_3 \qquad D = f_3 g_5 - f_5 g_3$$

$$H = (f_4 g_6 - f_6 g_4) f^2 + (f_4 g_7 + f_5 g_6 - f_6 g_5 - f_7 g_4) f + f_5 g_7 - f_7 g_5 .$$

Dividing by A and factorizing the polynomial we get

$$(1 - l_1 L)(1 - l_2 L)(1 - l_3 L) z_{t+1} = \frac{H}{A}\hat{w}_{t-1} \qquad \text{(A12)}$$

where

$$l_1 + l_2 + l_3 = -\frac{B}{A}, \qquad l_1 l_2 + l_1 l_3 + l_2 l_3 = \frac{C}{A}, \qquad l_1 l_2 l_3 = -\frac{D}{A}.$$

This equation system can be solved for the unknown reciprocals of the roots $l_1 - l_3$. We find one that is smaller than unity and denoting this root l_1, we can solve for the stable solution as in Sargent (1979, p179):

$$(1-l_1)z_{t+1} = \frac{H/A}{(1-l_2L)(1-l_3L)}\hat{w}_{t-1} = \frac{H/A}{l_2-l_3}\left(\frac{l_2}{1-l_2L} - \frac{l_3}{1-l_3L}\right)\hat{w}_{t-1}$$

$$= \frac{H/A}{l_2-l_3}\left(\frac{L^{-1}}{1-l_3^{-1}L^{-1}} - \frac{L^{-1}}{1-l_2^{-1}L^{-1}}\right)\hat{w}_{t-1} = \frac{H/A}{l_2-l_3}\left(\sum_{j=0}^{\infty} l_3^{-j}L^{-j} - \sum_{j=0}^{\infty} l_2^{-j}L^{-j}\right)\hat{w}_t \qquad \text{(A13)}$$

$$= \frac{H/A}{l_2-l_3}\left(\sum_{j=0}^{\infty} l_3^{-j}f^{j} - \sum_{j=0}^{\infty} l_2^{-j}f^{j}\right)\hat{w}_t$$

and hence we have the solution for z_{t+1}:

$$z_{t+1} = l_1 z_t + \frac{H/A}{l_2-l_3}\left(\frac{1}{1-f/l_3} - \frac{1}{1-f/l_2}\right)\hat{w}_t\,. \qquad \text{(A14)}$$

Solving analoguously for Δk_t we get:

$$(1-l_1L)(1-l_2L)(1-l_3L)\Delta k_{t+1} = \frac{M}{A}\hat{w}_{t-2} \qquad \text{(A15)}$$

where the roots are the same as above and

$$M = (f_6g_1 - f_1g_6)f^3 + (f_6g_2 + f_7g_1 - f_1g_7 - f_2g_6)f^2 + (f_7g_2 + f_6g_3 - f_2g_7 - f_3g_6)f + f_7g_3 - f_3g_7$$

and thus

$$\Delta k_{t+1} = l_1 \Delta k_t + \frac{M/A}{l_2 - l_3}\left(\frac{1}{1-f/l_3} - \frac{1}{1-f/l_2}\right)\hat{w}_{t-1}. \tag{A16}$$

These solutions hold for τ=t+1 and onwards, but not necessarily for τ=t-1, t. To find the solution for period t we use the linearized Euler equations for periods t and t+1 for z, and that for t+1 for k (since k is set one period in advance) and solve these 5 equations. The result is an approximate closed form solution:

$$z_t = a_{zz} z_{t-1} + a_{zk} \Delta k_t + a_{zw} w_t + a_{zy} \Delta y_t \tag{A17}$$

$$\Delta k_{t+1} = a_{kz} z_{t-1} + a_{kk} \Delta k_t + a_{kw} \hat{w}_t + a_{ky} \Delta y_t. \tag{A18}$$

(Note that Δy_t is normally not equal to zero.) To find the solution for the price we use a Taylor expansion of the inverted customer flow equation:

$$p_t - p_t^* = \ln\left[\frac{P_t}{P_t^*}\right] = \ln\left[\frac{1}{e}\left(1 + e - \frac{X_t}{X_{t-1}}\right)\right] = \ln\left[\frac{1}{e}\left(1 + e - \frac{X_t Y_t}{K_t}\frac{K_{t-1}}{X_{t-1}Y_{t-1}}\frac{K_t}{K_{t-1}}\frac{Y_{t-1}}{Y_t}\right)\right]$$

$$= \ln\left[\frac{1}{e}\left(1 + e - e^{z_t - z_{t-1} + \Delta k_t - \Delta y_t}\right)\right] \approx 0 - \frac{1}{e}\left[z_t - z_{t-1} + \Delta k_t - \Delta y_t\right]$$

$$= \frac{1 - a_{zz}}{e} z_{t-1} - \frac{1 + a_{zk}}{e}\Delta k_t - \frac{a_{zb}}{e} b_t - \frac{a_{zw}}{e}\hat{w}_t - \frac{1 - a_{zy}}{e}\Delta y_t \tag{A19}$$

Appendix 2: Data

All variables are in fixed prices and are mainly collected from the National Accounts.

Capital stock (K)
The capital stock series has been calculated using the perpetual inventory method described in Hansson (1991)

$$K_t^i = \left(1 - d^i\right)K_{t-1}^i + I_t, \qquad i = machinery, buildings$$

where the depreciation rate is 12.3 and 3.6 percent per year for machinery and buildings respectively. The total capital stock is simply:

$$K_t = K_t^m + K_t^b$$

Output (Q)
The output measure is gross output.

Total market demand (Y)
The foreign demand component is the sum of the volume indexes of industrial production in the OECD countries, weighted with the export shares. Domestic demand is measured by apparent consumption: Swedish gross production (Q) plus imports minus exports. Total market demand is then the sum of the two parts, weighted with the share of output going to the domestic and foreign market respectively:

$$Y_t = 0.65Y_t^D + 0.35Y_t^F$$

Domestic inputs (M)
Intermediate consumption at purchaser prices

Factor productivity (A)
The factor productivity is calculated as:

$$A_t = \frac{Q_t}{K_t^{0.19} M_t^{0.45} L_t^{0.36}}$$

The weights are the arithmetical averages for the factor shares in gross output using micro data from Enterprises, Financial Accounts collected by Statistics Sweden. The capital share is calculated as value added less total wage costs divided by total sales.

Producer price (P)
The producer price is the producer price index (1990=100).

Market price (P^0)
The competitive price is calculated as:

$$P_t^0 = 0.65P_t^D + 0.35P_t^F$$

where P_t^D is the domestic price index (1990=100) and P_t^F the foreign producer price index. P_t^D is the weighted sum of *P* and the import price index (0.75*P*+0.25*PI*), where the weights are determined by the share of imports in domestic apparent consumption.

P_t^F is the sum of foreign[28] producer price indexes, using competition weights[29]. The producer price indexes recalculated to Swedish kronor and normalized to 1990=100.

Effective relative wage $(\hat{W})$

The effective relative wage is the hourly wage including employers' contribution to social security divided by the product of factor productivity and the competitive price.

[28] USA, Canada, Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Switzerland, United Kingdom.

[29] Shares from OECD Main Aggregates Vol 1.

Table 1. Simulated Price and Investment Equations

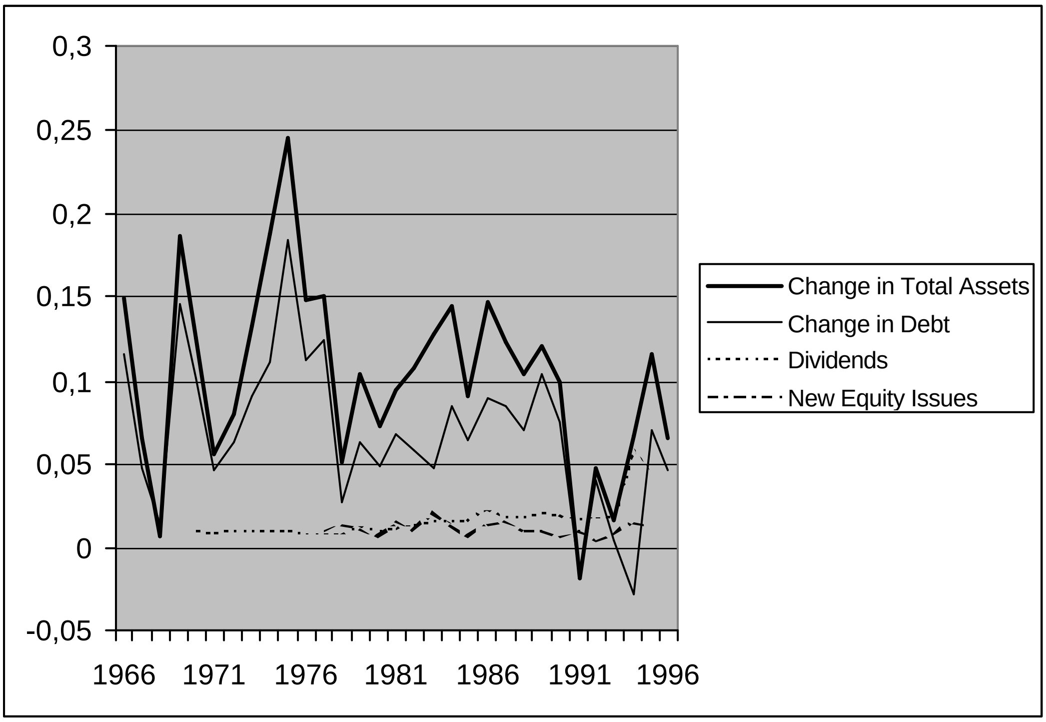
Independent variable –	1	2	3	4	5	6
	Baseline simulation	$g = 0.01$	$r = -1$	$e = 1$	$b = 0.94$	$q = 0.7$
Price equation						
$q_{t-1} - k_{t-1}$	**0.01**	0.18	0.02	0.14	0.01	0.01
Δk_t	**0.63**	-0.06	0.56	0.64	0.71	0.41
$w_t - a_t - p_t^0$	**0.62**	0.92	0.63	0.63	0.66	0.62
Δy_t	**0.01**	0.18	0.02	0.14	0.01	0.01
Investment equation						
$q_{t-1} - k_{t-1}$	**0.37**	0.70	0.49	0.33	0.35	0.52
Δk_t	**-0.57**	-0.77	-0.72	-0.55	-0.56	-0.70
$w_t - a_t - p_t^0$	**-0.17**	-1.09	-0.36	-0.24	-0.19	-0.25
Δy_t	**0.37**	0.70	0.49	0.33	0.35	0.52

Table 2. Estimated Price and Investment Equations

Independent variable –	1 **Baseline simulation**	2 **Baseline estimation**	3 **Lagged instr.**	4 **Lagged demand**	5 **Trend prod.**	6 **Reverse causality**	7 **1st-diff.**
Price equation $p_t - p_t^0$							
$q_{t-1} - k_{t-1}$	**0.01**	**0.0434 (0.0662)**	0.0133 (0.0625)	0.0405 (0.0625)	-0.0142 (0.0798)		-0.0358 (0.1353)
Δk_t	**0.63**	**0.8622 (0.2343)**	0.9305 (0.2674)	0.7661 (0.2437)	0.7965 (0.2876)		1.2527 (0.4563)
$w_t - a_t - p_t^0$	**0.62**	**0.4201 (0.0471)**	0.3833 (0.0691)	0.4448 (0.0588)	0.4851 (0.0551)		0.4887 (0.0681)
Δy_t	**0.01**	**0.0832 (0.0471)**	0.0097 (0.1248)	0.1076 (0.0563)	-0.0408 (0.0525)		0.1051 (0.0637)
Δy_{t-1}				0.0618 (0.0696)			
p-value		0.329	0.495	0.211	0.816		0.480
R^2		0.926	0.919	0.932	0.914		0.837
Investment equation Δk_{t+1}							
$q_{t-1} - k_{t-1}$	**0.37**	**0.1715 (0.0480)**			0.1826 (0.0572)	0.2109 (0.0549)	0.0553 (0.1221)
Δk_t	**-0.57**	**-0.0826 (0.1490)**			-0.0536 (0.2169)	0.0682 (0.1572)	0.1112 (0.3733)
$w_t - a_t - p_t^0$	**-0.17**	**-0.0917 (0.0248)**			-0.0876 (0.0321)	0.0457 (0.0798)	-0.1368 (0.0377)
Δy_t	**0.37**	**0.2395 (0.0398)**			0.2598 (0.0442)	0.2771 (0.0492)	0.1456 (0.0449)
$p_t - p_t^0$						-0.2805 (0.1373)	
p-value					0.453	0.364	0.291
R^2					0.853	0.863	0.897

Notes: Numbers in parenthesis are t-values. All estimations were done by GMM allowing for first order moving average and heteroscedasticity. Estimations included a constant, trend and trend squared, which are not reported. The next to last row shows the p-value for the test of overidentifying restrictions. There were modest signs of autocorrelation in the residuals, but only the first lag in the investment equation was significant.

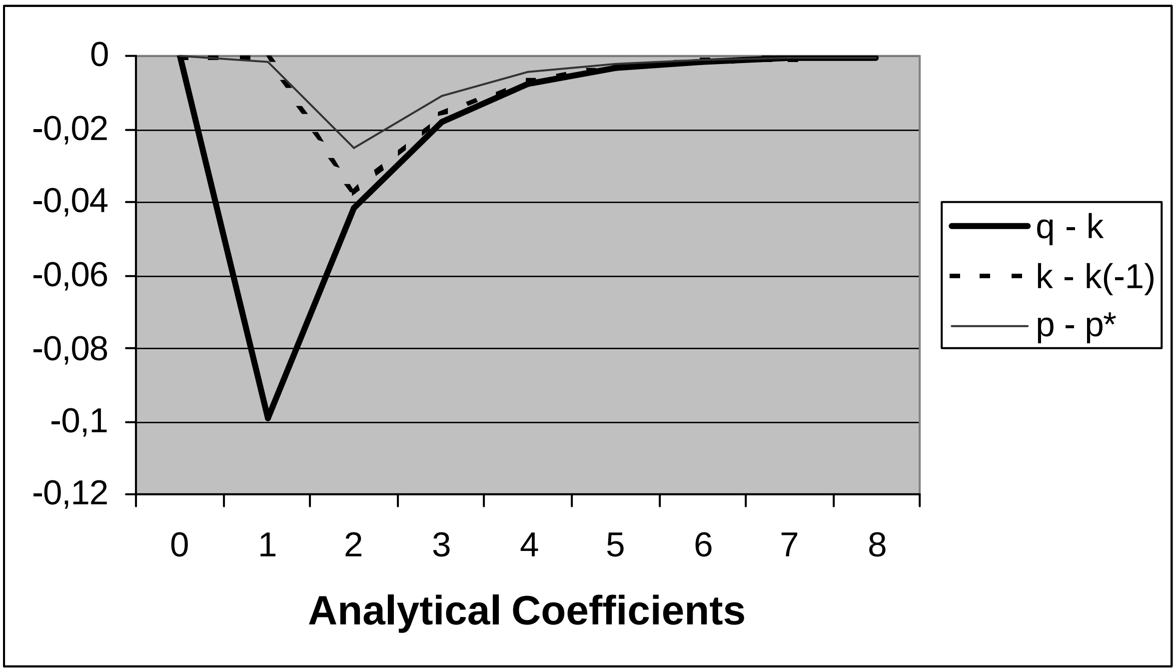
Figure 1. Sources of Finance for Swedish Manufacturing



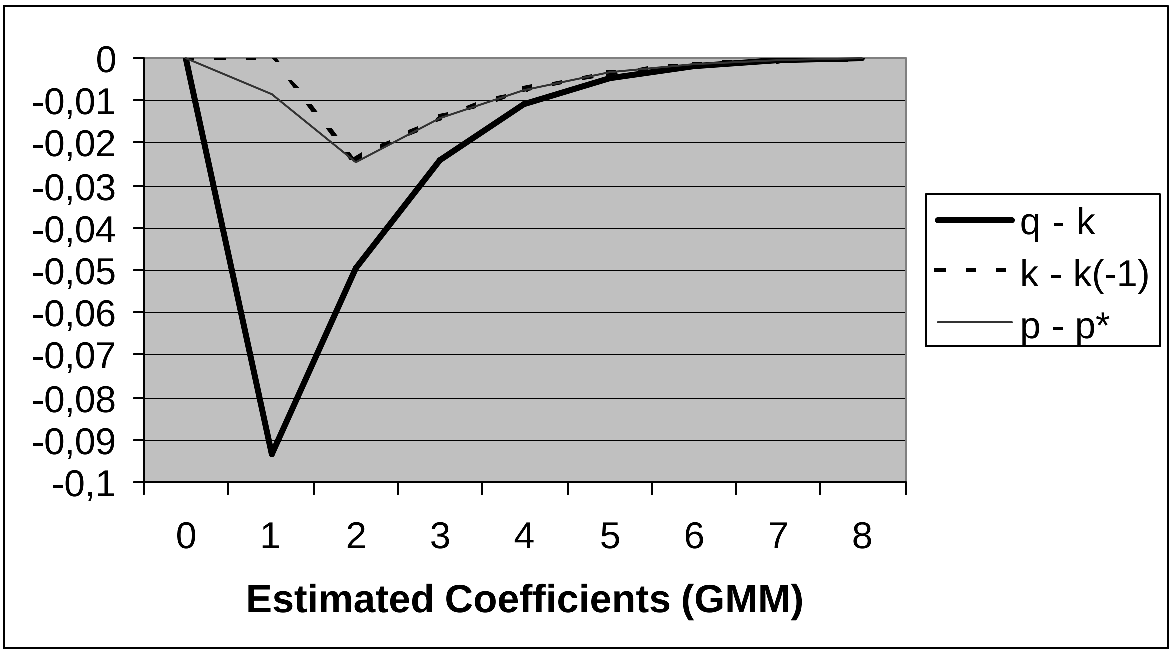
Note: All data in this figure is aggregate nominal accounting data for the manufacturing industry from the publication *Företagen*. All variables are measured relative to total assets in the previous period.

Figure 2. **The effect of a 10 percent permanent decrease in demand (Δy) in t=1.**

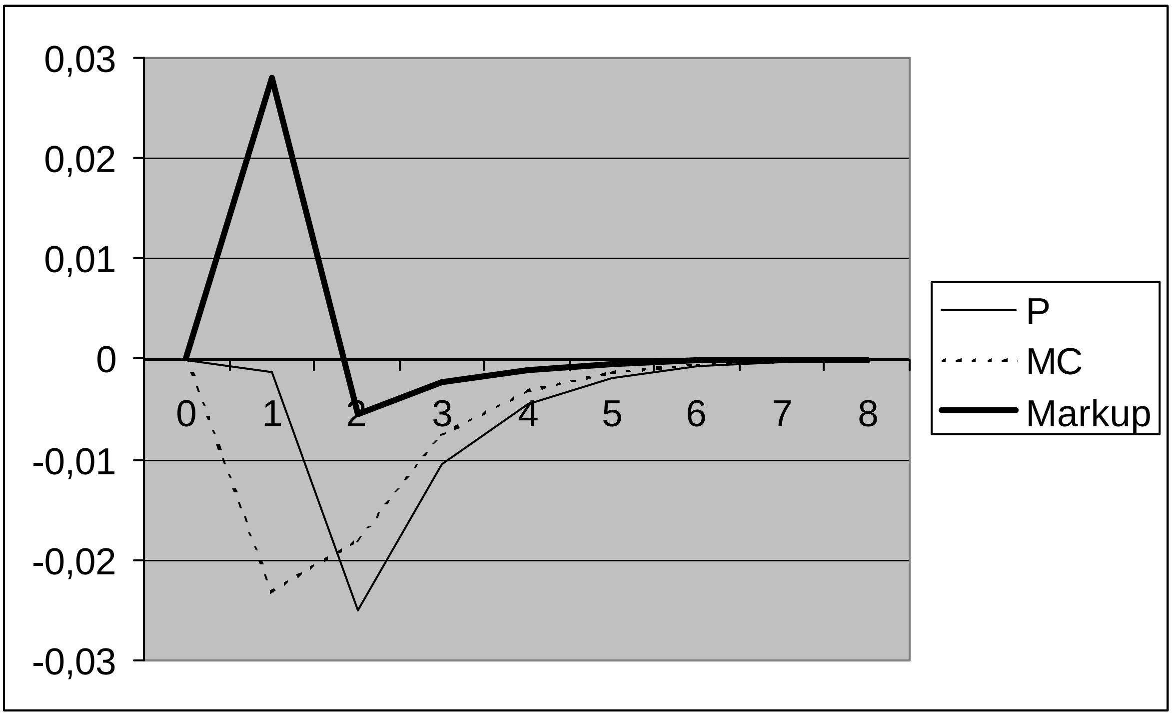
A. Production relative to capital, investments and price: analytical coefficients.



B. Production relative to capital, investments and price: estimated coefficients.



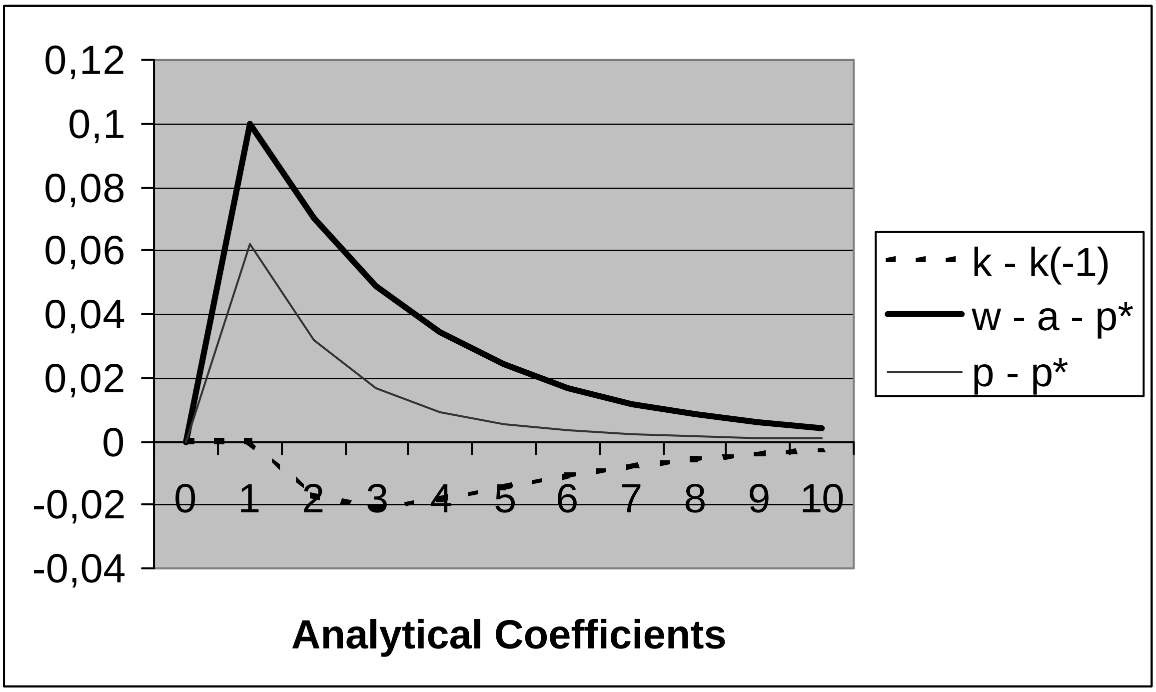
C. Price, marginal cost, and the markup: analytical coefficients.



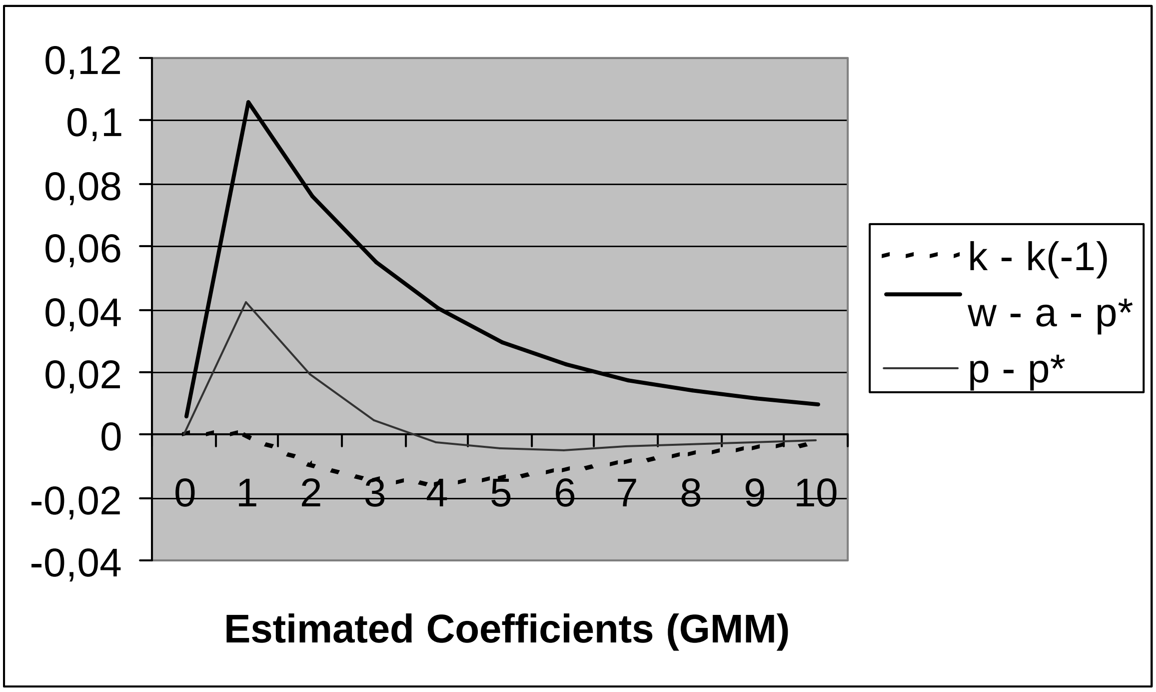
Note: All panels show log deviations from steady state except for dividends relative to capital.

Figure 3. The effect of a 10 percent increase in the price of the flexible factor (w-a-p^0).

A. Investment and price: analytical coefficients.

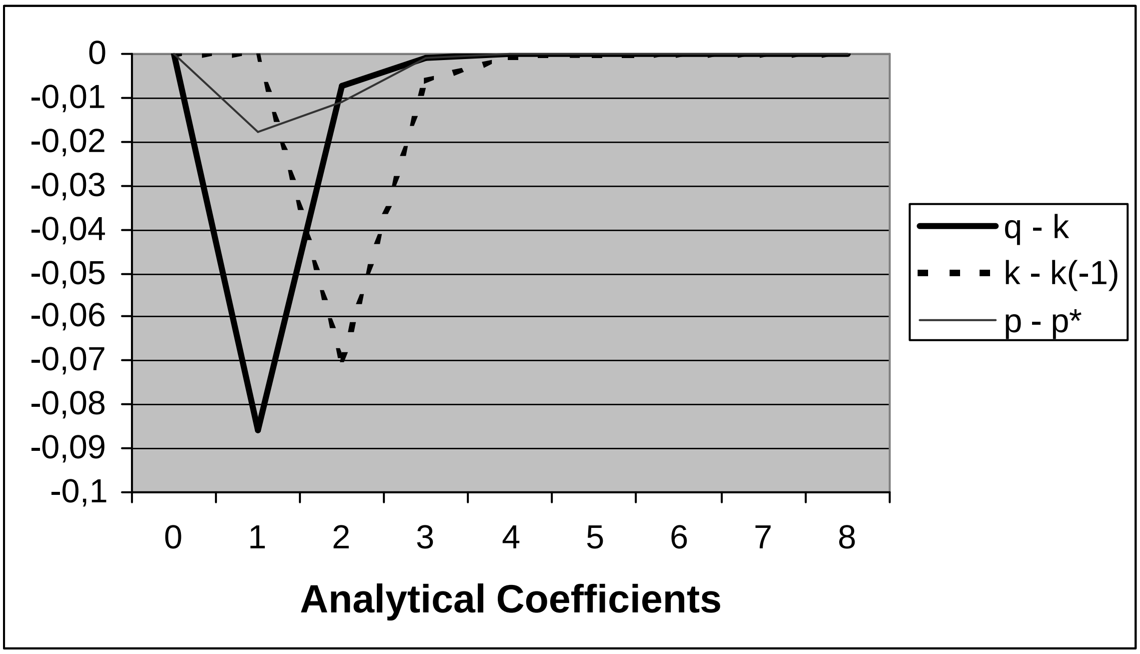


B. Investment and price: estimated coefficients.



Note: All panels show log deviations from steady state.

Figure 4. The effect of a 10 percent decrease in demand when there are no financial constraints (g=0)



Note: The figure shows log deviations from steady state.

Figure 5. Relative price and unit labor cost

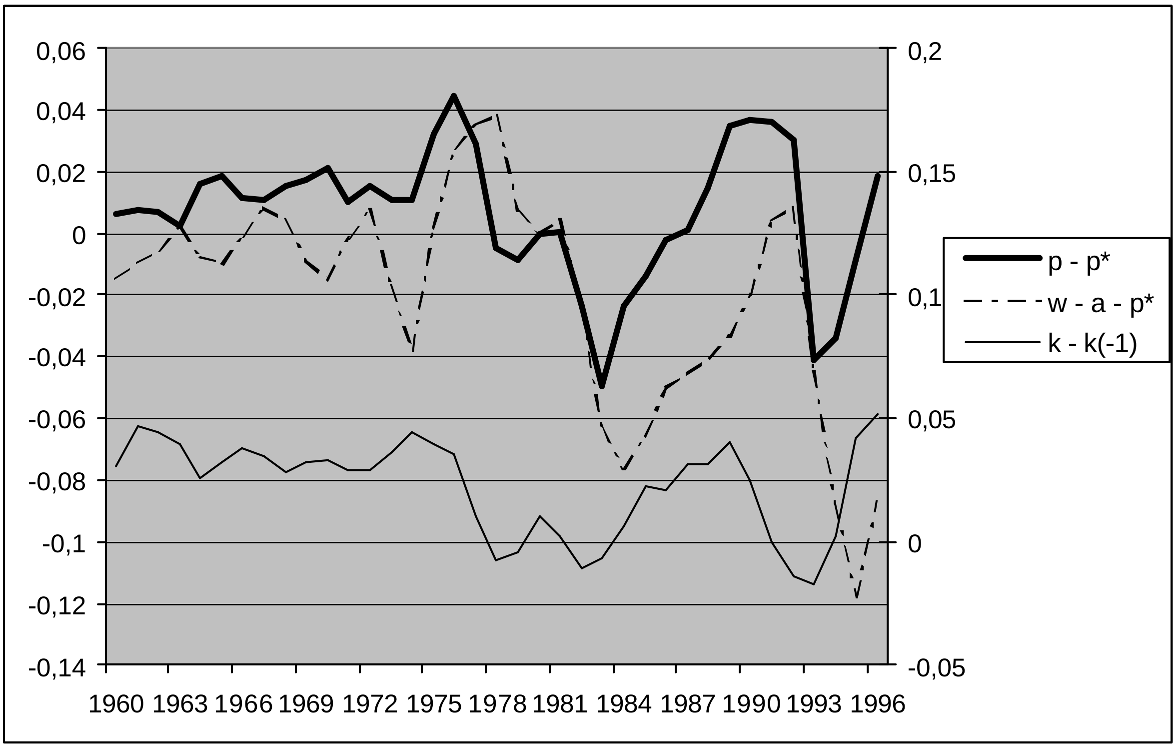


Figure 6. Change in demand and change in output

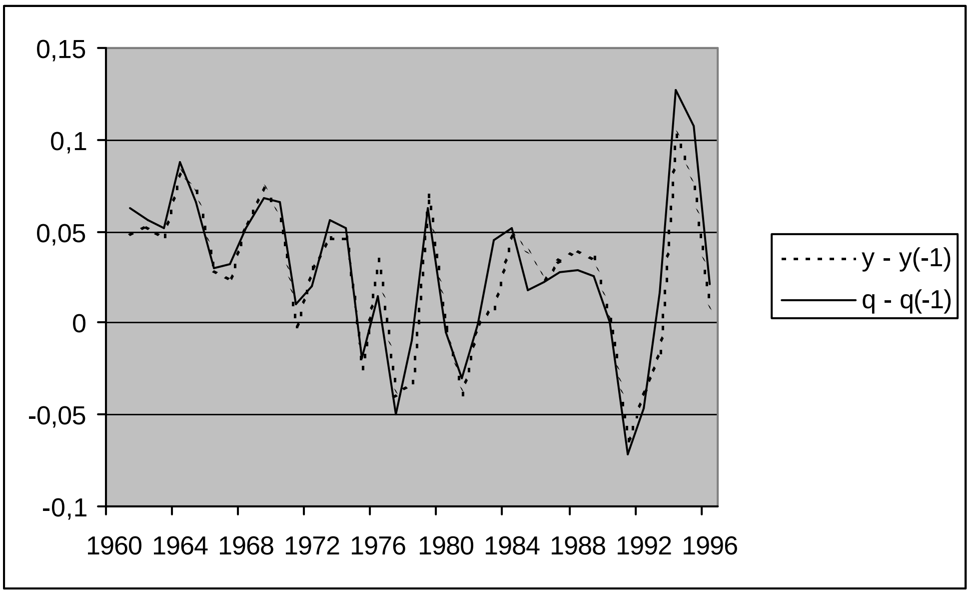


Figure 7. Output relative to capital and investments