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Price and Investment Dynamics: Theory and Plant Level Data*

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We construct a model of a firm competing for market share in a customer market and making investments in physical capital. The firm is financially constrained and there are implementation lags in investment. Our model predicts that product prices should depend on costs and competitors' prices, but respond weakly to demand shocks. Also, prices should be strongly related to investment. Estimating price and investment equations on panel data for Swedish manufacturing plants we find results which are qualitatively in line with these predictions, though the relation between investment and prices is stronger than predicted by our model.

Keywords: price rigidity, price equation, investment equation, credit constraint

JEL-codes: D43,E31,E32,E44,L11,L13,L16

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“This seeming inability to find a significant (and consistent!) impact of demand is surprising.” (Nordhaus, 1972, p. 35)

In classical microeconomic models, product prices move in such a way as to stabilize production. If demand increases, firms raise prices, and this dampens the demand for their products. But the link between demand and prices, which follows directly from textbook theory, has been hard to find in the data. Estimates of price equations typically show that prices respond strongly to factor prices, but are much less responsive to demand.¹ Bils and Chang (2000) confirmed this result in a recent study. Shea (1993) found that prices typically do rise with demand, but with a considerable lag.² Menu costs can explain slow price adjustment, but not an asymmetric response to cost and demand shocks.

On the macroeconomic level, researchers find similarly weak effects of demand on prices. Impulse-response functions from structural VAR models show very little movement of wages and prices in the first year after a monetary shock (Blanchard, 1989, Christiano, Eichenbaum and Evans, 1999). To fit this fact, modern macro-econometric models with sticky prices often incorporate an implausible degree of nominal price stickiness. Smets and Wouters (2005), for example, estimated the average duration of prices to be about two and a half years in the U. S. and the euro area. This is far longer than one finds in micro data (Bils and Klenow, 2004; see also Altig, Christiano, Eichenbaum and Linde, 2005). Backward-looking indexation schemes are commonly introduced in empirical macro models so as to make inflation more persistent (Christiano, Eichenbaum and Evans, 2005).

The puzzling behavior of prices suggests that some important elements are missing in the textbook treatment of price determination. Nominal rigidities cannot be the whole story but there must also be some real rigidity, which slows down price adjustment.³ In this paper, we argue that long-term *customer relations*, *financial constraints*, and interaction between prices and *investment* may generate real price rigidity and slow down price adjustment in response to a demand shock.

¹For references, see e.g. Nordhaus (1972), Gottfries (1991), Bils and Chang (2000).

²Much of the recent literature is concerned with the markup over marginal cost. Here, the results are mixed, and appear to depend on the treatment of labor hoarding and overhead labor. Chirinko (1994) and Ghosal (2000) found positive effects of demand measuring the markup by production value relative to variable cost and treating labor as a variable factor. This measure of variable cost disregards variations in the utilization of labor and the associated costs – see Basu and Fernald (2001). Bils (1987) and Rotemberg-Woodford (1991, 1999) tried to take account of variations in utilization and overhead labor, and found counter-cyclical markups.

³Ball and Romer (1990), Kimball (1995), Rotemberg and Woodford (1999), and Romer (2001) discuss how real rigidities slow down nominal price adjustment and increase the effects of nominal frictions.

In a customer market buyers repeatedly purchase a good. Customers who are attracted by low prices tend to remain loyal and customers lost because of high prices are hard to win back. The seminal paper by Phelps and Winter (1970) formalized this idea. They analyzed a firm's choice between a high price, which increases profits today, and a low price, which attracts customers and increases 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. In a recession, financially constrained companies abstain from price cuts in order to maintain cash flows and pay their debts; during booms, they can afford to pursue a more aggressive price policy. Empirical evidence consistent with this hypothesis is reported by Bhaskar, Machin and Reid (1993), Chevalier and Scharfstein (1996), Gottfries (2002) and Asplund, Eriksson and Strand (2005).

If firms are financially constrained and sell their products in a customer market, one would expect to see important interactions between investment in physical capital and investment in market share. High demand implies high cash flow, but also a need for additional capacity. High predetermined investment expenditure should make it more likely that a firm becomes financially constrained. The purpose of this paper is to explore this interaction between investment and price decisions theoretically and empirically.

We develop a dynamic model of a firm, which sells its output in a customer market. The firm has two assets: physical capital and the customer stock (market share). It can invest either in physical capital or in the customer stock, by charging a low price to attract new customers. The firm is financially constrained: it does not issue new shares, managers (or owners) dislike fluctuations in dividends, and only a fraction of its investments can be financed by borrowing.⁴ We also allow for the fact that the completion of an investment project is a prolonged process. According to Nickell (1978), the whole completion process takes about 23 months, whereas Hall (1977) found that investments are completed in 21 months. To capture this in a simple way, we assume an implementation lag of one year.

We solve the model numerically and find optimal decision rules for price and investment. Without financial constraints, we get conventional pricing behavior; prices respond positively to both cost and demand shocks. If financial constraints are important, we get sluggish price adjustment after a demand shock. To understand this, consider an unexpected permanent *decrease* in demand. With investment predetermined and demand falling, the firm finds itself in a financial squeeze. In order to finance ongoing investments

⁴A large body of empirical work shows that investment is related to cash flow and other financial variables, suggesting imperfections in capital markets; see e. g. Chirinko and Schaller (1995), Hubbard (1998).

and avoid drastic cuts in dividends, the financially constrained firm abstains from price cuts. In subsequent periods, investment is reduced; the firm becomes less financially constrained and cuts price in order to increase its market share. Hence, there is a form of lagged price adjustment after a demand shock.

A wage increase has an immediate effect on the price because higher wage costs raise marginal cost and also make firms more financially constrained. Thus, our model can explain an asymmetric response to cost and demand shocks. Furthermore, the model predicts a positive relation between investment and prices because, *ceteris paribus*, high predetermined investment tends to make firms more financially constrained. This is a new and testable prediction, which differentiates our theory from other explanations of countercyclical markups, such as those presented by Rotemberg and Saloner (1986), Bilal (1989), Rotemberg-Woodford (1992), Ireland (1992), and Bilal and Chang (2000).

To explore whether the dynamics of prices and investment are qualitatively consistent with our model, we estimate structural price and investment equations on a large data set for manufacturing plants 1990-1998. The data source is unique; it provides a wide coverage of plants in Swedish industry and is not limited to data for a certain branch or a small number of products as is usual in micro data studies of pricing behavior. Plant specific price indices have been constructed by Statistics Sweden using a mixture of plant specific unit values and disaggregate producer price indices.

To disentangle how prices respond to cost and demand shocks, we exploit the openness of the Swedish economy. Using industry data for export and import shares, foreign and domestic production and prices, and exchange rates, we construct firm-specific measures of demand and competitors' prices. Industries differ in their dependence on foreign markets and in their exposure to foreign competition and this is a source of considerable cross industry variation in demand and competitiveness which should help us to disentangle the effects of costs, demand, and competitors' prices. To deal with simultaneity, we use foreign demand and prices as instruments. These variables are reasonably exogenous for a small open economy, and can be seen as a small open economy alternative to the demand instruments used by Hall (1988), Shea (1993) and Ghosal (2000).

As predicted by our theory, wage costs and competitors' prices both affect the price, but demand variables have small and mostly insignificant effects. Investment has a positive effect on the price which is both statistically and quantitatively significant. In fact, the estimated effect is larger than predicted by our model. Combined with adjustment lags in investment,

this implies slow price adjustment after a demand shock. This real rigidity may play an important role in the propagation of business cycle shocks.

The theory is set up in Section 1 and the numerical solution is presented in Section 2. Data and variable definitions are presented in Section 3 and estimation issues are discussed in Section 4. Baseline results are presented in Section 5, Section 6 contains some robustness checks, and Section 7 concludes.

1. A Model of Price and Investment Dynamics

The firm's customer stock is X_t and each customer buys Y_t^σ units, where Y_t is a demand shock, so production is

$$Q_t = X_t Y_t^\sigma; \sigma > 0. \quad (1)$$

The customer stock changes slowly, increasing or decreasing over time depending on the price charged by the firm, P_t , relative to the average market price, P_t^0 :

$$\frac{X_t - X_{t-1}}{X_{t-1}} = -\varepsilon \left(\frac{P_t - P_t^0}{P_t^0} \right); \varepsilon > 0. \quad (2)$$

This relation can be motivated in alternative ways. Phelps and Winter (1970) provided theoretical foundations for such an equation based on imperfect information, Gottfries (1986) considered a mix of imperfect information and switching costs, while Klemperer (1987, 1995) emphasized switching costs. Ravn, Schmitt-Grohé and Uribe (2006) derive similar dynamics assuming that consumers form habits over individual varieties of goods.

The functional form of the demand function determines the importance of competitors' prices in the optimal price policy. The more convex the demand curve, the more important are competitors' prices for the firm's optimal price. In macroeconomic models with static monopolistic competition, demand is often assumed to be constant-elastic, i.e. concave, so the markup is independent of competitors' prices. We have chosen the demand curve which is linear in the relative price because it leads to pricing behavior which is roughly consistent

with what one finds empirically; most studies find that the price depends on costs as well as on competitors' prices.⁵

The production function takes the CES form in capital, K_t , a flexible production factor, F_t , and exogenous technology, A_t :

$$Q_t = \left[(1 - \alpha)(A_t F_t)^\rho + \alpha K_{t-1}^\rho \right]^{\frac{1}{\rho}} ; 0 < \alpha < 1. \quad (3)$$

There is an adjustment cost associated with investment:

$$C(\Delta K_t, K_{t-1}) = \frac{c}{2} \left(\frac{\Delta K_t}{K_{t-1}} \right)^2 P_t^k K_{t-1}, \quad (4)$$

where P_t^k is the price of capital goods. We do not allow for fixed adjustment costs or irreversibility. Both are likely to be important, but they would make the model much more complicated (Carlsson and Laséen, 2005).

As is well known, dividends are much more stable than investment and borrowing, and new share issues play a modest role in the financing of investments; most investment is financed by retained earnings and borrowing. 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 or because owners or managers fear loss of control.⁶

ii) Owners or managers dislike fluctuations in dividends. In a small entrepreneurial firm, where the owner has all his capital invested in the firm and lives on the dividends, the owner's preference for smooth consumption translates into a preference for smooth dividends.⁷ More generally, it seems clear that managers or owners dislike fluctuations in

⁵But there is a natural information asymmetry in a customer market, which tends to make demand convex. If a firm raises its price above the average market price, some of its customers may be induced to look for a better price, but if it reduces its price below the market price, few of the other firms' customers will discover the lower price (see e.g. Stiglitz (1979), Woglom (1982), Ball and Romer (1990)). See also Gottfries (2002) for discussion of the functional form of demand in a customer market model.

⁶If existing owners have inside information they will tend to sell off shares exactly when the firm is overvalued in the stock market. This adverse selection problem can lead to a breakdown of the market for new shares.

⁷Entrepreneurial investment is important. Moskowitz and Vissing-Jorgensen (2002) found that the total value of private equity is similar to that of public equity in the U. S. Furthermore, private equity is poorly diversified and concentrated in the hands of managers. About 75 percent of all private equity is owned by households for whom it constitutes at least half of their total net worth, and households with entrepreneurial equity invest on average

dividends, maybe because dividends are used to signal long-term profitability. For example, Brav, Graham, Harvey and Michaely (2005) surveyed 384 financial executives and found that “... maintaining dividend policy is a priority on par with investment decisions. Managers express a strong desire to avoid dividend cuts, except in extraordinary circumstances.” To capture this preference for smooth dividends, we assume that the manager maximizes the present value of utility, where utility in each period is a concave function of the dividend.

iii) Lenders are completely uninformed about the firms’ prospects and they therefore ask for collateral to lend to the firm. A fixed fraction of the capital stock can be used as collateral, so there is an upper limit on borrowing. Let θ be the fraction of investment that can be financed by borrowing.

iv) The required steady state return on equity (the discount rate used to discount utility) is substantially higher than the interest rate on debt, so the firm always borrows as much as possible. This assumption is made to highlight the role of financial constraints. Tax advantages of debt are an obvious reason why firms may find it advantageous to use debt finance as much as possible.⁸

This specification of financial constraints is obviously very stylized. Our purpose is to capture key cyclical aspects of financial constraints, which arise when both debt and equity finance are limited and firms have a preference for smooth dividend payments. In effect, the firm’s capital structure is fixed exogenously. To explain the evolution of the capital structure is a difficult task, and beyond the scope of the present paper.

Assumption iv above implies that all income, which is not used to finance investment, is paid out as dividend.⁹ Real dividends are:

$$\begin{aligned} \hat{D}_t &= \frac{1}{P_t^c} \left[P_t Q_t - W_t F_t - P_t^k \Delta K_t - \delta P_t^k K_{t-1} - \frac{c}{2} \left(\frac{\Delta K_t}{K_{t-1}} \right)^2 P_t^k K_{t-1} + \theta P_t^k K_t - (1+i_{t-1}) \theta P_{t-1}^k K_{t-1} \right] \\ &= \frac{1}{P_t^c} \left[P_t Q_t - W_t F_t - P_t^k \left((1-\theta) \Delta K_t + \delta K_{t-1} + \frac{c}{2} \frac{(\Delta K_t)^2}{K_{t-1}} + r_t \theta K_{t-1} \right) \right] \end{aligned} \quad (5)$$

more than 70 percent of their private holdings in a single company in which they have an active management interest.

⁸For the constraint to be binding when there are there are positive demand shocks, there must be a sufficient difference between the two rates. In reality, we may expect some firms to be financially constrained, and some not. Also, firms may be financially constrained in bad times and unconstrained in good times. This would make the analysis more complicated, however.

where W_t is the price of the flexible factor, P_t^c is the relevant consumer price index, used to deflate dividends, and $r_t \equiv (1 + i_{t-1})P_{t-1}^k / P_t^k - 1$. Letting $D_t = P_t^c \hat{D}_t / P_t^0$ and using (2), (3) and (4) we can write:

$$D_t = \left(\frac{1 + \varepsilon}{\varepsilon} - \frac{X_t}{\varepsilon X_{t-1}} \right) X_t Y_t^\sigma - \frac{W_t}{A_t P_t^0} \left[\frac{\left(X_t Y_t^\sigma \right)^\rho - \alpha K_{t-1}^\rho}{1 - \alpha} \right]^{1/\rho} - \frac{P_t^k}{P_t^0} \left[(1 - \theta) \Delta K_t + \delta K_{t-1} + \frac{c}{2} \frac{(\Delta K_t)^2}{K_{t-1}} + r_t \theta K_{t-1} \right] \quad (6)$$

The implementation lag in investment is introduced by assuming that current investment is predetermined. We abstract from strategic considerations and from sticky prices. In each period, the firm decides about P_t and K_{t+1} . The manager knows current demand and costs and takes the average market price as given, so choosing price is equivalent to choosing the customer stock. The firm chooses X_t, K_{t+1} to maximize

$$E_t \left\{ \sum_{\tau=t}^{\infty} \beta^{\tau-t} \frac{\hat{D}_\tau^{1-\gamma} - 1}{1-\gamma} \right\}; \quad 0 < \beta < 1, \gamma \geq 0, \quad (7)$$

where β is a discount factor determining the required return on equity. This utility function assures that dividends are non-negative, and the larger γ is, the more the manager/owner dislikes fluctuations in dividends.¹⁰ Two Euler equations characterize the optimal decision in period t . The first Euler equation reflects the optimal choice of customer stock:

$$E_t \left\{ D_t^{-\gamma} \left(\frac{P_t^0}{P_t^c} \right)^{1-\gamma} \left[\left(\frac{1 + \varepsilon}{\varepsilon} - \frac{2X_t}{\varepsilon X_{t-1}} \right) Y_t^\sigma - (1 - \alpha)^{-1/\rho} \frac{W_t}{A_t P_t^0} \left[1 - \alpha \left(\frac{K_{t-1}}{X_t Y_t^\sigma} \right)^\rho \right]^{\frac{1-\rho}{\rho}} Y_t^\sigma \right] + \beta D_{t+1}^{-\gamma} \left(\frac{P_{t+1}^0}{P_{t+1}^c} \right)^{1-\gamma} \left(\frac{X_{t+1}}{X_t} \right)^2 \frac{Y_{t+1}^\sigma}{\varepsilon} \right\} = 0; \quad (8)$$

⁹We assume that the return on financial assets is lower than the interest rate on debt, so firms do not hold any financial assets. It would be straightforward to add a liquidity demand for financial assets in our model.

The last 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: current marginal revenue is lower than marginal cost. Because customers are valuable, the optimal price is lower than the price that maximizes current profits. The second Euler equation reflects optimal choice of investment:

$$E_t \left\{ -D_{t+1}^{-\gamma} \left(\frac{P_{t+1}^0}{P_{t+1}^c} \right)^{1-\gamma} \frac{P_{t+1}^k}{P_{t+1}^0} \left(1 - \theta + c \frac{\Delta K_{t+1}}{K_t} \right) + \beta D_{t+2}^{-\gamma} \left(\frac{P_{t+2}^0}{P_{t+2}^c} \right)^{1-\gamma} \right. \\ \left. \left[\alpha (1-\alpha)^{-1/\rho} \frac{W_{t+2}}{A_{t+2} P_{t+2}^0} \left[\left(\frac{X_{t+2} Y_{t+2}^\sigma}{K_{t+1}} \right)^\rho - \alpha \right]^{\frac{1-\rho}{\rho}} + \frac{P_{t+2}^k}{P_{t+2}^0} \left(1 - \theta - \delta + c \frac{\Delta K_{t+2}}{K_{t+1}} \left(1 + \frac{\Delta K_{t+2}}{2K_{t+1}} \right) - r_{t+2} \theta \right) \right] \right\} = 0. \quad (9)$$

The fraction of investment expenditure, including adjustment cost, which is not debt-financed, is taken out of dividends, which reduces utility during the period when the investment is carried out. During the following period, labor costs are reduced, investment can be reduced, and debt must be paid back with interest in order to return to the original trajectory.

2. Numerical Solution of the Model

Since the model is too complex to solve analytically, we solve it numerically. The objective is to show that financial constraints can have important effects on pricing behavior. We solve the model assuming that P_t^c / P_t^0 is expected to be constant and disregarding variations in the relative price of capital and the real interest rate. 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.¹¹ In order to solve for price and investment as functions of current state variables, we assume that the log of Y_t is a random walk and that the log of $W_t / A_t P_t^0$ follows a first order autoregressive process.

¹⁰This specification can be seen as a generalization relative to models with a non-negativity constraint on dividends.

¹¹We also checked the solution using the program Dynare, available at www.cepremap.cnrs.fr/~michel/dynare/.

In our baseline simulation, we take the period to be one year and use the parameter values listed in *Table 1*. We set ρ close to zero so that the elasticity of substitution between the factors of production is one (Cobb-Douglas). The parameter α should be equal to the capital share in total costs, which is approximately 20 percent. Assuming that the depreciation rate is 12 percent for machines and 4 percent for buildings, and that about 2/3 of the capital stock consists of machines, we get a depreciation rate δ equal to 9 percent. The parameter ε is the within-year price elasticity of demand at the steady state (at $P/P^0 = 1$) and σ is the elasticity with respect to the demand variable Y_t . Based on estimates reported below, we set $\varepsilon = 0.5$ and $\sigma = 0.8$. The adjustment cost parameter, c , is set to 1, broadly in line with estimates by Whited (1992), Gilchrist and Himmelberg (1995) and Lindberg (2000). The share of debt financing, 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 Based on estimates using micro data described below, the coefficient ρ_w in the autoregressive process for $W_t / A_t P_t^0$, is set to one half.¹³

The concavity of the utility function γ is harder to pin down. We set $\gamma = 2$ in the baseline simulation. The steady-state value of $w_t - a_t - p_t^0$ determines whether the firm is growing or contracting in the steady state. We set it in such a way that the firm is not growing in the steady state, which implies a steady state markup equal to 19 percent of the marginal cost. With these parameter values, we get the following log-linear decision rules:

$$p_t - p_t^0 = 0.62 (w_t - a_t - p_t^0) + 0.03 (q_{t-1} - k_{t-1}) + 0.03 \Delta y_t + 0.50 \Delta k_t, \quad (10)$$

$$\Delta k_{t+1} = -0.09 (w_t - a_t - p_t^0) + 0.27 (q_{t-1} - k_{t-1}) + 0.22 \Delta y_t - 0.35 \Delta k_t. \quad (11)$$

Lower case letters denote logs and constant terms have been left out. The wage cost has a large effect on the price but demand has a small effect. By construction, the coefficient for Δy_t is σ times that for $q_{t-1} - k_{t-1}$. High predetermined investment raises the price because investment in physical capital crowds out investment in market share. In the investment

¹²We calculated net debt as short and long term debt minus financial assets, excluding shares in related companies. Capital includes machines, buildings and inventories.

¹³Estimating first order autoregressive processes for logs we found coefficients close to unity for Y_t and close to 0.5 for W_t / P_t^0 . Productivity was represented by a trend in the latter case.

equation, wage costs have a negative effect, there is an “accelerator effect” of demand, and high investment in the previous period reduces the need to invest today.

Figure 1 illustrates the simulated effect of a 10 percent, unexpected, permanent *decrease* in demand per customer (Y_t^σ). Initially, the price is not much affected. To understand this, note that there are two opposing effects on the price from a demand shock. Lower demand implies lower marginal cost, giving an incentive to cut the price. But at the same time, profits fall, making it hard to finance ongoing investments. The firm finds itself in a financial squeeze, which creates an incentive to raise the price to increase current profits. As it turns out, these two effects largely cancel each other out and the price changes very little. In the subsequent period, investment is reduced and the firm becomes less financially constrained, so it can afford to cut its price to increase the market share. The result is lagged price adjustment after the demand shock. Since output and marginal cost decrease, and the price is initially kept unchanged, the markup on marginal cost increases substantially in the downturn.¹⁴

Figure 2 illustrates the effect of a 10 percent *increase* in the price of the flexible factor. Contrary to the case of a demand shock, the effect of a cost shock is immediate. The predicted response to a cost shock is similar to what we get in a static model. An increase in wage costs raise marginal cost and also make the firm more financially constrained.

Table 2 illustrates how sensitive our simulation results are to changes in the parameter values. Each column reports coefficients in the price and investment equations when we change one parameter, keeping the other parameters at baseline values. If we set $\gamma = 0$, so the firm maximizes the present value of dividends, we get a much more conventional price response to a demand shock. Now demand has a substantial and immediate effect on the price. Also, the effect of investment on the price turns negative. Now the complementarity between real capital and market share dominates: the more capital the firm will have in the future, the more valuable is it to have a large customer base. This is illustrated in *Figure 3*. Customer relations do not, by themselves, lead to countercyclical markups.¹⁵

The next column in *Table 2* shows price and investment policies when the firm is able to finance less of its investment by borrowing ($\theta = 0.2$). Investment is a heavier financial

¹⁴The decision rules were derived assuming that the borrowing constraint always binds. But a sufficiently large *positive* demand shock can put the firm in a position where it finds it more advantageous to pay back debt than to further cut the price to compete for market shares. For the parameter values used in the baseline simulation this occurs only if the unexpected positive demand shock is very large.

¹⁵Bils (1989) and Ravn, Schmitt-Grohe, and Uribe (2006) construct models where the markup is countercyclical because demand shocks make demand more elastic. Here, the elasticity is assumed to be independent of demand.

burden and the effect on the price is increased. If, instead, all investment can be financed by borrowing ($\theta = 1$) the interaction between investment and price disappears.

With the capital stock predetermined, the slope of the marginal cost curve depends on the substitutability between capital and labor. It seems plausible that the Cobb-Douglas production function implies too large substitutability in the short-run, so that the marginal cost curve is too flat.¹⁶ To examine the effect of lower substitutability we set $\rho = -1$, implying an elasticity of substitution equal to one half. The coefficient for demand increases but is still small; the countercyclical markup dominates. Finally, we consider a higher adjustment cost: $c = 3$. This reduces the accelerator effect, but has little direct effect on the price policy. Changes in the other parameters ($\alpha, \varepsilon, \beta$) have small effects on the optimal price and investments policies (not shown).

Thus we see that financial constraints can potentially have large effects on pricing behavior. Just how important financial constraints really are is hard to say. To get some idea how strong financial constraints are in the baseline model, we did two calculations.¹⁷ First, we calculated the effective (shadow) required marginal rate of return on equity investment $D_t^{-\gamma} / (\beta D_{t+1}^{-\gamma}) - 1$ in the baseline case where $\gamma = 2$. *Figure 4* shows how dividends and the required return evolve after a 10 percent decrease in demand. We see that the shadow required return rises from 8 to 12.3 percent when the shock occurs; then it quickly returns to 8 percent as dividends stabilize on a new and lower level.

A second way to evaluate the strength of the financial constraints is to evaluate the loss, in terms of present value of dividends, from pursuing the constrained policy where you smooth dividends ($\gamma = 2$) instead of the policy that maximizes present value of dividends ($\gamma = 0$). It turns out that this loss is very small. With a 10 percent positive or negative shock to demand, the loss in present value of dividends from pursuing the constrained adjustment policy is less than 0.2 percent of the initial yearly dividend. For a ten percent cost shock we find similar results. Thus we conclude that, for the magnitude of shocks considered here, our financial constraints do not lead to unreasonable shadow prices of funds, nor do they imply very costly deviations from the present value maximizing price and investment policies.

¹⁶Adjustment costs for labor would make the marginal cost curve steeper while the possibility to vary the utilization of capital would make it flatter; see Rotemberg and Woodford (1999) for a discussion.

¹⁷We are very grateful to Simon Gilchrist and Stephen Bond for raising these issues.

3. Data and Variables

To examine whether actual price and investment dynamics is qualitatively consistent with our theory, we now turn to estimation of the price and investment equations using panel data for Swedish manufacturing firms. Data are drawn from three different sources. The first is a newly constructed database, provided by Statistics Sweden and the Riksbank, covering all industrial plants with at least 20 employees in Sweden. This database includes annual records of plant specific sales, labor inputs, wage costs and producer price indices for the years 1985-1998 and capital inputs for 1990-1998. From this database, a *panel of plants* in the manufacturing sector has been constructed. The investigation is limited to the manufacturing sector. This is by far the largest sector in Sweden –accounting for about 60 percent of industrial gross production – and has a more complete coverage in the database. The data refers to plants, but in 78 percent of the observations used here, there is one plant per firm, so in practice, the panel can be seen as a panel of firms. The second source is *accounting data for manufacturing firms* in Sweden. This database, also provided by Statistics Sweden, contains income statements, information on the destination of sales, and balance sheet information. It is used to calculate the ratio of exports to total sales and the debt to asset ratio. We do not have access to identification numbers that allow us to match individual plants and firms, so these ratios are calculated on the industry level. Finally, we use *import prices and industry data* from Statistics Sweden and from the STAN database at OECD.

In general, the variables are constructed using the most disaggregated data available. *Producer price*, *wage cost* and *output* are plant-specific variables. The *capital stock* is calculated from plant-specific investment, but industry-specific ratios are used to generate starting values. The *market price* is a mixture of plant-specific, industry-specific and aggregate variables. The *demand* variable is constructed from industry aggregates at the 2-digit and 5-digit level. Several variables are constructed as weighted averages of original series in logs. We use fixed weights because the number of time periods is small and the shares are intended to measure general characteristics of the industry (exposure to foreign competition) rather than developments in particular years.

Sample selection: Capital stocks were calculated using the perpetual inventory method, starting in 1989, and for this procedure to be consistent across firms, we excluded plants that are not ongoing throughout the entire sample period. Also, industries with less than four plants at the 5-digit level were removed. Plants in industries with very few competitors are either oligopolies or monopolies, where the customer market model is less applicable, or they compete primarily with foreign producers, for which only aggregated price data are available.

This sample selection procedure results in a balanced panel of 2321 plants observed over the period 1990-1998. Robustness checks with an unbalanced panel, inclusion of smaller plants and smaller industries were performed; the results are not sensitive to the sample selection procedure.

Sector classifications: Plants are classified according to the 5-digit ISIC 92 system. About 20 percent of the plants changed industry classification during the sample period. These plants are reclassified to belong to the same industry over time. This is necessary since some explanatory variables are constructed from industry level data. For each plant, we use the industry number that is observed for the longest period of time. There are 151 5-digit industries (e. g. cheese 15511), 74 3-digit industries (dairy products 155), and 21 2-digit industries (food products and beverages 15). The definitions of variables are listed below. Subscript i denotes plant, subscript j denotes 5-digit industry and subscript m denotes 3-digit industry level. More aggregate data is used when data for 3-digit level is missing.

Producer price (p_{it}): The *plant-specific producer price index* is constructed by Statistics Sweden using a mix of plant-specific unit values for the main products of the plant, and price indices from the producer price system. Whether unit values or producer price indices are used to calculate the price change for a particular product depends on judgment of the quality of the data. Unit values are not used if data are missing, the implied price change is outside a postulated acceptable range, the unit of quantity measurement has changed, or the type of good is such that quantity data is not meaningful. For such goods, a disaggregate producer price index for the relevant class of goods is used instead. Then price changes for the different goods are used to compile a price index for the individual plant.¹⁸

Wage cost (w_{it}): Wage cost per worker is calculated as the total wage sum (including all wages to employees, cash compensation and other taxable benefits) divided by number of employees.¹⁹ We include only the wage as cost variable because materials often come from the same industry and are subject to the same shocks as the dependent variable in the price equation, leading to serious simultaneity problems (see Basu (2000) for a discussion).

¹⁸Less than half the price data comes from plant-specific unit values. Still, very detailed information about product classifications and disaggregate producer price data are used to construct the other prices, so the index should contain substantial information. We have not been able to obtain tags showing which firm-level price indices are based exclusively on firm-specific information. Often, it is a mixture. This measurement error may bias our estimated coefficients downwards because movements in the individual firm's relative price are underestimated.

¹⁹Data on hours is not available for the entire sample period. Variations in overtime are relatively small in Sweden; see Carlsson (2003).

Production (q_{it}): Production is measured as the value of total sales deflated by the plant-specific producer price.

Investment (Δk_{it}): Investment is the log difference of the capital stock. The capital stock is computed from investment data using the perpetual inventory method, $K_{it} = (1 - \delta)K_{it-1} + I_{it}$, applied separately to machinery and buildings. Real investment in machinery and buildings is calculated by dividing nominal investment expenditure by the manufacturing industry investment deflator. The database for industrial plants contains investment but does not include balance sheet information, so book values of capital stocks cannot be used as starting values. Instead, data on capital stocks and gross output at the 2-digit industry level are used to calculate industry-specific capital output ratios for machinery and buildings in 1989.²⁰ The output of each plant is then multiplied by these two ratios in order to generate starting values for the stocks of machinery and buildings.²¹

Market price (p_{it}^0): The market price should reflect the price set by plant i 's competitors. In the original Phelps-Winter (1970) model, customers are assumed to know the prices of their present suppliers. Customers of different firms meet randomly, compare prices, and switch to the supplier with the lower price. This makes it more probable that they compare with the price of a large competitor. Also, large firms have more resources for marketing. Thus, it seems plausible that larger competitors are more important. We therefore constructed an average producer price for *domestic* competitors of firm i , \bar{p}_{it} , as the mean producer price in the industry at the 5-digit level, excluding plant i 's producer price, and weighting each plant's price with its share of total sales.

Many Swedish firms sell a large share of their output in foreign markets and compete with foreign suppliers in the domestic market. Since we do not have data on each firm's prices and market shares in different markets, we model the firm as if it has to set the same price in all markets.²² The average market price, which is relevant for plant i , is defined as: $p_{it}^0 = (1 - s_j) [(1 - v_m) \bar{p}_{it} + v_m p_{mt}^i] + s_j p_t^f$. The domestic part of the market price is a weighted sum of the average industry producer price \bar{p}_{it} , defined above, and the industry (3-digit level) import price p_{mt}^i . The weight v_m is industry-specific (3-digit level) import penetration,

²⁰In this case, industries are classified according to the SNI69 system. There are 8 industries at the 2-digit level (31-38).

²¹The geometric depreciation rate for machinery is industry-specific and the depreciation for industrial buildings is set to 0.031. Values are taken from Katz and Herman (1997).

²²The logic of our model suggests that firms should set different prices in different markets (pricing to market). Hence, we must think of our results as capturing average pricing behavior across markets.

defined as the ratio of imports to apparent consumption (gross output plus import minus export) in 1990 calculated from the STAN industrial data base at OECD.²³ The foreign price p_t^f is an aggregate variable and consists of competition-weighted foreign export prices for manufacturing converted to Swedish currency. It is weighted by the export share, s_j , calculated as the sample period mean of the industry (5-digit level) share of foreign sales in total sales.

Change in market demand (Δy_{jt}): This variable is meant to capture growth in demand in the markets where the firm has market share. It is defined as a weighted sum of the change in domestic and foreign industry demand: $\Delta y_{jt} = (1 - s_j) \Delta y_{mt}^d + s_j \Delta y_{mt}^f$. The weight s_j is the export share, defined above. The change in domestic demand, Δy_{mt}^d , is measured by the change in apparent consumption (production plus imports minus exports) at the 2-digit industry level. The change in foreign demand, Δy_{mt}^f , is competition-weighted 2-digit level industrial production in a number of OECD countries. The domestic and foreign demand components are taken from the OECD STAN industrial database.

Differences in the exposure to foreign demand and competition are an important source of variation between different industries. The recession in the early 1990s was much deeper in Sweden than in most other countries and the large depreciation of the Swedish currency in 1992-1993 affected exporting firms much more than those supplying the domestic market. This cross-industry variation should help us identify the effects of costs, price competition, and demand on prices and investment.

4. Empirical Specification and Estimation Method

We estimate three relations: a price equation, an investment equation, and a demand relation.

The price equation is:

$$p_{it} - p_{it}^0 = b_w (w_{it} - p_{it}^0) + b_q (q_{it-1} - k_{it-1}) + b_y \Delta y_{jt} + b_k \Delta k_{it} + b_i + b_m t + d_t + \varepsilon_{it}. \quad (12)$$

Productivity and other omitted factors are captured by a plant-specific constant b_i , industry-specific (3-digit level) trends $b_m t$, time dummies d_t , and firm-specific shocks ε_{it} . Time

²³Data on gross output, export and import was not available for all 3-digit industries; for those missing, more aggregate industry data was used.

dummies are included because the number of time periods is small, so results without time dummies may be affected by unobserved macroeconomic shocks which affect all firms.

If there are industry-wide shocks, the market price (p_{it}^0) and industry demand (Δy_{jt}) are endogenous. We therefore use foreign demand and foreign prices to instrument for the market price and industry demand.²⁴ Foreign prices are translated into Swedish currency using the nominal exchange rate, which is endogenous on the macro level, but time dummies are included in the estimated equations. Investment and nominal wages are taken to be *predetermined* but we suspect substantial *measurement errors* in these firm-specific variables. Data comes from surveys and one may suspect that respondent errors contaminate the data.²⁵ We therefore instrument these variables by the corresponding industry aggregates.²⁶ Hence we construct an “aggregate instrument” for investment as the mean in time t of the corresponding variable for all plants in the same industry (2-digit level) except plant i . For example: $\Delta \bar{k}_{it} = \frac{1}{N-1} \sum_{f \neq i}^N \Delta k_{ft}$ is used as instrument for Δk_{it} , where N is the number of plants in the same industry. Analogous instruments are constructed for w_{it} and $q_{it-1} - k_{it-1}$.²⁷

Thus, the first set of estimates is done using *Instrument set I* in *Table 3*. The within-groups transformation is used to take account of plant-specific effects. These estimates are denoted “within.” All estimations are done using the two-step GMM procedure (ivreg2,gmm) in Stata version 8.²⁸

In the above specification, we include a deterministic industry-specific trend to represent productivity and other omitted factors. An alternative is to think of the productivity trend as stochastic, in which case it is appropriate to estimate the equations in first differences with industry-specific constants. Also, lagged output and the capital stock are taken to be predetermined, but not strictly exogenous variables, so with a relatively short panel, the within-groups transformation may produce biased estimates (Nickell, 1981). For these reasons we also estimate the price equation in first difference form using only lagged instruments:

²⁴We disregard world-wide industry-specific technology shocks.

²⁵See Nelson (1995) for a demonstration of attenuation bias when multiple regressors are measured with errors. If only one regressor is measured with error, the coefficient on the badly measured variable will be biased towards zero, and all other coefficients will be biased in unknown directions. See also Greene (1997) pp. 435-442.

²⁶Instruments of this type have been used in panels of aggregate data, for example in Levitt and Snyder (1997) and Harrigan (1997).

²⁷These “aggregate instruments” are not quite the same as aggregate industry data. The firm itself is excluded and the variables are not weighted by output but simple averages across firms. In practice, we get qualitatively similar results if we use aggregate industry data as instruments.

²⁸This can be thought of as a generalization of two-stage least squares which allows for conditional heteroscedasticity.

$$\begin{aligned} \Delta p_{it} - \Delta p_{it}^0 = & b_k (\Delta k_{it} - \Delta k_{it-1}) + b_w (\Delta w_{it} - \Delta p_{it}^0) + b_q (\Delta q_{it-1} - \Delta k_{it-1}) + b_y (\Delta y_{jt} - \Delta y_{jt-1}) \\ & + b_m + d_t + \Delta \varepsilon_{it} \end{aligned} \quad (13)$$

using *Instrument Set II* in *Table 3*. The equation for investment is analogous to the price equation and estimated in the same way. We also estimate a log-linearized product demand equation derived from (1) and (2):

$$\Delta q_{it} = \sigma \Delta y_{jt} - \varepsilon (p_{it} - p_{it}^0). \quad (14)$$

5. Results

As a reference point, let us first estimate a conventional price equation. The first order condition of a monopolistic firm with demand $D(P_{it} / P_{it}^0)$ and a Cobb-Douglas production function can be written as a relation between $p_{it} - p_{it}^0$, $w_{it} - p_{it}^0$ and $q_{it} - k_{it}$. In *Table 4* we report estimates of such a standard supply relation. We reproduce the puzzle mentioned in the introduction. Higher wage costs raise prices, but the coefficient for $q_{it} - k_{it}$ is negative; the supply curve is not upward-sloping. The Hansen J test indicates misspecification.

In columns four and five we report estimates of the price equation derived from our customer market model with financial constraints. The results are qualitatively similar for regressions in levels and differences. The elasticity with respect to wage costs is about 0.6, close to what we found in the numerical simulation. If wage costs increase, Swedish firms will raise prices above the market average, and gradually lose customers. The level of production at the start of the period and the change in demand both have negative coefficients, though significant in only one case.

The coefficient for investment is positive, as predicted by our theoretical model, and strongly significant. In fact, it is much larger than we found in the simulations. This we cannot fully understand. Taken literally, our estimates imply that a one standard deviation increase in investment (0.026)²⁹ brings about a four percent increase in the price (0.026*1.5).

Turning to the investment equation in *Table 5*, we see that higher wage costs reduce investment and there is an accelerator effect of demand. The coefficient for investment was

²⁹This refers to the within measure on the 3-digit level. The (within) standard deviation is 0.022 on the 2-digit level and 0.103 on the firm level. The latter is likely to be exaggerated by measurement errors.

expected to be negative because high investment today reduces the need to invest next period. We find this only for the equation in levels. One possible reason is that there may be omitted variables which cause positive serial correlation in investment.

Table 6 shows estimates of the product demand equation (14). Demand and the relative price have the expected effects. The very significant effect of demand shows that the demand variable, which was constructed using industry data, does indeed capture important demand shocks. As in Gottfries (2002), the within-year elasticity with respect to the relative price is well below unity.

6. Alternative Estimates of Price and Investment Equations

So far we have not included any measure of *productivity* in the price and investment equations. The reason is the well-known problems associated with the measurement of technology shocks. High measured factor productivity in boom periods may reflect high utilization of factors rather than true technology shocks (Basu and Fernald, 2001, Carlsson, 2003, Alexius and Carlsson, 2005). To see whether inclusion of productivity affects our results, we include a firm-specific measure of productivity, calculated as

$a_{it} = (3/2)q_{it} - (1/2)k_{it} - n_{it}$, where n_{it} is employment (cf. equation (3)). The last two columns in *Table 4* show the results when we include productivity in the price equation. The coefficient for productivity is negative and significant, but substantially smaller than the coefficient for the wage. The coefficients for $q_{it-1} - k_{it-1}$ and Δy_{jt} change from negative to positive, but they are small and statistically insignificant in three out of four cases.

When productivity is included in the investment equation, it appears difficult to separate the effect of productivity from the accelerator effect of demand (see the last two columns of *Table 5*).

We did several other robustness checks. We excluded *outliers*, defined as observations outside ten times the inter-quartile range above the 75th percentile and below the 25th percentile. The results were very similar to the baseline results. We also allowed for *clustering* on industry-year. The standard errors increased somewhat, but the qualitative results were unchanged.

Omission of industry trends or time dummies had small effects on the estimates. Equations without time dummies were rejected by the Hansen test, maybe because of omitted macro shocks, which affect all firms.

Our model is a completely real model where the relative price is explained by wage costs relative to foreign prices and other real variables. Consequently, *nominal neutrality* is imposed in the baseline specification. But is nominal neutrality consistent with the data? To test this, we estimated a price equation with p_{it} as dependent variable, and w_{it} and p_{it}^0 entering separately on the right-hand side. Both coefficients turned out positive, but with large standard errors, and the restriction that the coefficients sum to unity could not be rejected. The other coefficients were qualitatively similar. Imposing nominal neutrality is important for the estimation of the pass-through of costs, b_w , but not for the other results.

Up to now, we have disregarded *nominal price rigidity*. This was done to keep the model clean and avoid confusion of the mechanisms discussed here with nominal price rigidity. But sticky prices are an alternative, or complementary, explanation of countercyclical markups. One way to allow for predetermined prices is to assume that firms try to implement the decision rules above, but have to set prices without full information about current variables. Under rational expectations, we may then estimate the decision rules using as instruments a set of lagged variables that are assumed to be known by price setters. Thus, we estimated price and investment equations with all variables in instrument sets I and II lagged one period. The coefficient estimates were qualitatively similar but the estimates were somewhat less precise.

Also, there may be *simultaneity problems* if wages and investment are not completely predetermined. Again, the use of lagged instruments should reduce this problem.

One might suspect that the positive correlation between investment and prices is *spurious*, arising because investment and prices both react slowly to demand shocks. A simple way to test this is to add a lagged demand term Δy_{jt-1} on the right-hand side of the price equation. If lagged demand has a positive effect on the price and the effect of investment is reduced, this indicates that the effect of investment on the price is spurious. We found no significant effect of Δy_{jt-1} .

Another possibility is *reverse causation*. If prices rise for some unknown reason, this may cause high investment rather than the reverse. To test this, we included the relative price in period t in the equation for investment in period $t+1$. Under the maintained hypothesis that investment takes time, we would expect a positive coefficient if there is reverse causation. There was no significant effect of the relative price. We also tried to include $p_{it+1} - p_{it+1}^0$ in the investment equation, adding p_{it} to the instrument list; the results were similar.

Small firms are typically considered to be more financially constrained. Also, financial constraints may be related to capital intensity and the level of debt. To see if there are any systematic differences between different groups of firms, we tried to split the sample based on variables which may be indicators of financial constraints. Thus we split the sample by *size*, *capital output ratio*, and *debt to asset ratio*. Size is measured by the number of employees and debt ratio is short and long term debt relative to the balance sheet total for the *industry*. (We do not have financial information for plants.) Both are measured as averages over the sample period. We found no robust and significant differences between different groups of firms. As can be seen in *Table 7*, the results for most subgroups are qualitatively similar to the results for the whole sample. Since small firms are typically thought to be more often financially constrained than large firms, the absence of systematic differences between different groups of firms may be taken as evidence against our theory. Alternatively, preference for smooth dividends and constraints on indebtedness are important determinants of behavior for all types of firms.

Finally, we have argued that it is important to take account of *measurement errors* when estimating behavior using firm-level data. But how important are measurement errors and the resulting attenuation bias? One indication of the importance of measurement errors can be obtained by looking at estimates at alternative levels of aggregation. If the measurement errors are uncorrelated across plants, one would expect the attenuation bias to be less severe when the equation is estimated on higher industry levels since the measurement errors would tend to cancel out to a higher degree the higher the level of aggregation. To examine whether there is evidence of this, we ran simple OLS regressions of the price equation on different levels of aggregation. As can be seen in *Table 8*, the coefficients for the wage and investment do indeed rise with the aggregation level. The coefficient for investment increases from 0.0390 in the plant-level estimation, to 0.5898 at the 2-digit industry level. If we instead do IV (aggregating instruments listed in *Table 2* to the sector level) we get coefficients similar to those in the last column in *Table 8* independent of the level of aggregation. These results are consistent with the view that microeconomic data contains massive measurement errors, so it is important to use appropriate instruments when estimating behavior using such data.

7. Conclusion

Our theoretical model is based on three key ideas: the market share is an important asset of the firm, firms are sometimes financially constrained, and there are implementation lags in investment. Starting from these postulates, two conclusions are inescapable. First, pricing decisions are effectively dynamic investment decisions which may be affected by financial constraints. Second, there is likely to be some interaction between investment in productive capacity and competition for market shares since the two types of investment compete for available financial resources at a given point in time.

We have shown, theoretically, that a model with these realistic features can explain the common empirical finding: that costs have large effects on prices, whereas demand has a small effect. Such a differential response is predicted by our theoretical model because cost and demand shocks have opposite financial consequences. Higher costs make firms more financially constrained. Higher demand makes firms less financially constrained, so they want to invest more in their market shares.

We investigated price and investment behavior of Swedish manufacturing firms using a large dataset for manufacturing plants. In line with earlier findings, we found that prices depend on wage costs and competitors' prices, but respond little to demand. We also found a positive relation between investment and prices. Such a relation is predicted by our theory, but the estimated coefficient is larger than predicted by our model.

What we have presented is a theory of *real price rigidity*. It is a partial analysis and nominal rigidities have been disregarded. More specifically, our theory explains why, for given wages and competitors' prices, the firm's optimal price responds slowly to a demand shock. In itself, our theory says nothing about aggregate price adjustment or inflation persistence. But as emphasized by Ball and Romer (1990) and Rotemberg and Woodford (1999), real rigidity increases the effects of nominal frictions. If an increase in demand has a negative effect on the *desired* markup (the markup that the firm would set if there were no nominal frictions) this "real price rigidity" amplifies the effects of nominal frictions. Hopefully, our theory can help to understand why the short run aggregate supply curve is so flat, and why monetary policy affects inflation with such a long lag.

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Table 1

Parameter values for baseline simulation

Description	Parameter	Value
Substitution parameter ($\rho = 0$ is Cobb-Douglas)	ρ	0.001
Capital share (in Cobb-Douglas case)	α	0.2
Depreciation	δ	0.09
Cost of adjustment for investment	c	1.0
Within-year price elasticity of demand	ε	0.5
Elasticity of demand with respect to demand shock Y	σ	0.8
Real interest rate on borrowing	r	0.04
Discount factor for dividends (required return on equity is 8 percent)	β	0.92
Fraction of investment financed by borrowing	θ	0.5
Concavity of utility function (preference for smooth dividends)	γ	2.0
Persistence of cost shock	ρ_w	0.5

Table 2

Simulated Price and Investment Equations

Independent variable	Baseline simulation	$\gamma = 0$	$\theta = 0.2$	$\theta = 1$	$\rho = -1$	$c = 3$
<i>Price equation</i>						
$w_t - a_t - p_t^0$.62	.60	.63	.60	.62	.62
$q_{t-1} - k_{t-1}$.03	.27	.04	.03	.05	.04
Δy_t	.03	.22	.03	.02	.04	.03
Δk_t	.50	-.18	.76	-.01	.47	.49
<i>Investment equation</i>						
$w_t - a_t - p_t^0$	-.09	-.07	-.08	-.10	-.15	-.07
$q_{t-1} - k_{t-1}$.27	.21	.25	.28	.36	.17
Δy_t	.22	.17	.20	.22	.29	.14
Δk_t	-.35	-.22	-.35	-.28	-.46	-.22

Note: Baseline equations are equations (10) and (11), derived using parameter values listed in Table 1. Columns show price and investment equations when we change one parameter at the time. All variables are in logs. w_t is wage cost, a_t is a technology shock, p_t^0 is market price, q_{t-1} is production in the previous period, k_{t-1} is capital stock in the previous period, Δy_t is the change in exogenous demand, and Δk_t is the (predetermined) change of the capital stock.

Table 3

Instrument sets

I	$v_c \bar{w}_{it}, v_c p_t^f, v_c \bar{w}_{it-1}, v_c p_{t-1}^f, \bar{q}_{it-1} - \bar{k}_{it-1}, s_j \Delta y_{jt}^f, \Delta \bar{k}_{it}$
II	$v_c \bar{w}_{it}, v_c p_t^f, v_c \bar{w}_{it-1}, v_c p_{t-1}^f, v_c \bar{w}_{it-2}, v_c p_{t-2}^f, \bar{q}_{it-2} - \bar{k}_{it-2}, s_j \Delta y_{jt}^f, s_j \Delta y_{jt-1}^f, \Delta \bar{k}_{it-1}$

Note: Variables are defined in Section 3. $v_c = (1 - s_j)v_m + s_j$ where v_m is import penetration and s_j is the export share of sales.

Table 4

Price equation.

Dependent variable is price relative to market price, $p_{it} - p_{it}^0$

Estimation method	within	difference	within	difference	within	difference
Instrument set	I	II	I	II	I and $\bar{k}_{it-1}, \bar{n}_{it-1}$	II and $\bar{k}_{it-2}, \bar{n}_{it-2}$
$w_{it} - p_{it}^0$	0.3216** (0.0280)	0.5344** (0.0405)	0.6864** (0.1025)	0.6305** (0.0949)	0.5199** (0.0871)	0.6273** (0.0880)
$q_{it} - k_{it}$	-0.1481** (0.0139)	-0.2375** (0.0259)				
$q_{it-1} - k_{it-1}$	-	-	-0.3640** (0.0508)	-0.1511 (0.0819)	0.0351 (0.1103)	0.0423 (0.1046)
Δy_{jt}	-	-	-0.0296 (0.0924)	-0.1133 (0.0730)	0.2680* (0.1217)	0.0691 (0.0993)
Δk_{it}	-	-	2.1432** (0.3389)	1.5285** (0.3454)	1.5671** (0.3159)	1.3170** (0.3305)
a_{it}					-0.3141** (0.0825)	-0.2500** (0.0983)
Hansen J (p-value)	0.0000	0.0000	0.5175	0.0134	0.1626	0.1065
# Plants / # Obs.	2321/20889	2321/18568	2321/20889	2321/18568	2321/20889	2321/18568

Note: $w_{it} - p_{it}^0$ is wage cost relative to market price, $q_{it} - k_{it}$ is production relative to capital stock, Δy_{jt} is the change in demand, Δk_{it} is the change in the capital stock, taken to be predetermined, a_{it} is a measure of factor productivity. All variables are in logs. Industry trends and time dummies included. Estimation by two-step GMM procedure (ivreg2, gmm) in Stata version 8. Instrument sets are defined in Table 2. Numbers in parentheses are standard errors. ** and * denote 1 percent and 5 percent significance level respectively.

Table 5

Investment equation.

Dependent variable is the change of the capital stock, Δk_{it+1}

Estimation method	within	difference	within	difference
Instrument set	I	II	I and $\bar{k}_{it-1}, \bar{n}_{it-1}$	II and $\bar{k}_{it-2}, \bar{n}_{it-2}$
$w_{it} - p_{it}^0$	-0.2506** (0.0446)	-0.2393** (0.0611)	-0.2200** (0.0459)	-0.2263** (0.0586)
$q_{it-1} - k_{it-1}$	0.1177** (0.0225)	0.0225 (0.0503)	0.0272 (0.0610)	-0.0078 (0.0642)
Δy_{jt}	0.1538** (0.0383)	0.1429** (0.0467)	0.0708 (0.0634)	0.0878 (0.0589)
Δk_{it}	-0.2137 (0.1539)	0.2380 (0.2128)	-0.0754 (0.1815)	0.1966 (0.2019)
a_{it}			0.0703 (0.0428)	0.0502 (0.0549)
Hansen J (p-value)	0.0683	0.9670	0.1238	0.9171
# Plants / # Obs.	2321/18568	2321/16247	2321/18568	2321/16247

Note: See note in Table 4.

Table 6

Log linearized product demand equation.

Dependent variable is the change in production, Δq_{it}

Estimation method	within	difference
Δy_{jt}	0.9810** (0.1266)	0.8526** (0.1211)
$p_{it} - p_{it}^0$	-0.5094** (0.1820)	-0.3429 (0.2279)
Hansen J (p-value)	0.6700	0.0196
# Plants / # Obs.	2321/18568	2321/18568

Note: Δy_{jt} is the change in demand and $p_{it} - p_{it}^0$ is the price relative to market price.Industry trends and time dummies included. Estimation by two-step feasible GMM procedure (ivreg2,gmm) in Stata version 8. Instruments in column 1 are $s_j \Delta y_{jt}^f, v_c \bar{w}_{it}, v_c p_t^f$.Instruments in column 2 are the same plus $s_j \Delta y_{jt-1}^f, v_c \bar{w}_{it-1}, v_c p_{t-1}^f$.

Numbers in parentheses are standard errors. ** and * denote 1 percent and 5 percent significance level respectively.

Table 7

Sample Splits by Size, Capital Intensity, and Debt Level.

Dependent variable is price relative to market price, $p_{it} - p_{it}^0$

Est. method	within			difference		
Instrument set	I	I	I	II	II	II
Size	small	medium	large	small	medium	large
$w_{it} - p_{it}^0$	0.7064** (0.2473)	0.8191** (0.2275)	0.4684** (0.1074)	0.4980** (0.1074)	1.0147** (0.2303)	0.6089** (0.1298)
$q_{it-1} - k_{it-1}$	-0.4210* (0.1803)	-0.2952** (0.1102)	-0.3479** (0.0518)	-0.2297 (0.1251)	-0.1024 (0.1451)	-0.1152 (0.0948)
Δy_{jt}	-0.1074 (0.3612)	0.0368 (0.1751)	0.0039 (0.0847)	-0.2994* (0.1280)	-0.2745* (0.1283)	-0.0502 (0.0931)
Δk_{it}	3.0132* (1.3633)	2.0364** (0.5815)	1.6478** (0.3600)	0.8006 (0.4404)	1.2391** (0.4374)	1.6672** (0.4984)
Hansen J (p-value)	0.5860	0.3419	0.0667	0.0155	0.8163	0.0179
# Plants / # Obs.	785/7065	770/6930	766/6894	785/6280	770/6160	766/6128
Cap. intensity	low	medium	high	low	medium	high
$w_{it} - p_{it}^0$	0.3842** (0.1043)	0.7235** (0.1796)	0.5666** (0.1065)	0.7686** (0.1263)	0.3901** (0.1362)	0.5724** (0.0712)
$q_{it-1} - k_{it-1}$	-0.3676** (0.0784)	-0.3424** (0.0854)	-0.2156** (0.0532)	-0.0041 (0.1067)	-0.3540** (0.1254)	-0.0428 (0.0497)
Δy_{jt}	0.0937 (0.1161)	-0.2394 (0.1486)	0.1689 (0.1035)	-0.0890 (0.0945)	-0.2032* (0.0809)	-0.2755** (0.0603)
Δk_{it}	2.2091** (0.5469)	1.8645** (0.4719)	1.2299** (0.2672)	1.2022** (0.4298)	1.0949** (0.3045)	0.4859** (0.2315)
Hansen J (p-value)	0.0020	0.6780	0.0004	0.5406	0.0122	0.0000
# Plants / # Obs.	774/6966	774/6966	773/6957	774/6192	774/6192	773/6184
Debt/Assets	low	medium	high	low	medium	high
$w_{it} - p_{it}^0$	0.4459** (0.0911)	0.3361** (0.0694)	0.5929** (0.1143)	0.4268** (0.0960)	0.6351** (0.0791)	0.8254** (0.1507)
$q_{it-1} - k_{it-1}$	-0.3040** (0.0580)	0.1048* (0.0437)	-0.4743** (0.0683)	-0.0865 (0.1059)	0.1409* (0.0556)	-0.1977* (0.0974)
Δy_{jt}	-0.0518 (0.2353)	-0.1242 (0.0637)	-0.1552 (0.1037)	-0.6918** (0.1351)	0.0122 (0.0363)	0.0846 (0.1678)
Δk_{it}	1.3913** (0.2580)	0.9845** (0.2597)	0.9230 (0.5360)	0.9514** (0.2323)	0.2898 (0.2060)	1.2205 (0.9236)
Hansen J (p-value)	0.0031	0.0009	0.0030	0.0000	0.0000	0.6158
# Plants / # Obs.	779/7011	801/7209	741/6669	779/6232	801/6408	741/5928

Note: See note to Table 4. Industry trends and time dummies included.

Table 8

Attenuation Bias and Aggregation.

Dependent variable is relative price, $p_{it} - p_{it}^0$

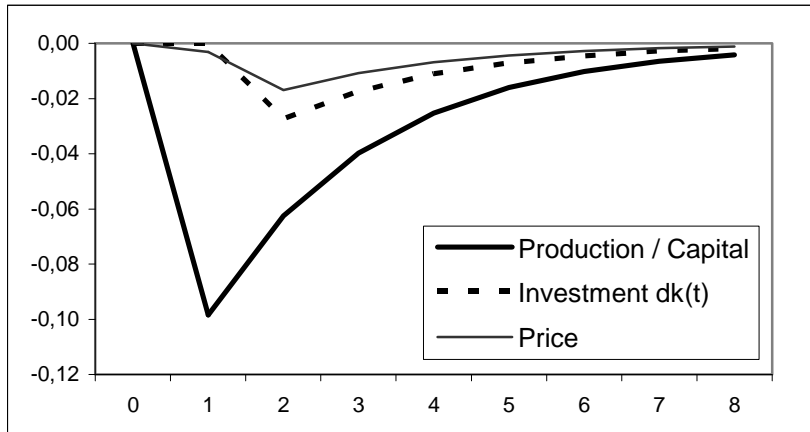
Level of aggregation	Plant	5-digit	3-digit	2-digit
$w_{it} - p_{it}^0$	0.0484** (0.0034)	0.1963** (0.0163)	0.2655** (0.0232)	0.4156** (0.0224)
$q_{it-1} - k_{it-1}$	-0.0155** (0.0016)	0.0323** (0.0095)	0.0336** (0.0154)	-0.0075 (0.0207)
Δy_{jt}	-0.1652** (0.0059)	-0.1482** (0.0149)	-0.1455** (0.0211)	-0.1158** (0.0268)
Δk_{it}	0.0390** (0.0041)	0.2092** (0.0288)	0.2646** (0.0519)	0.5898** (0.0804)
# Individuals / # Obs.	2321/20889	151/1359	57/513	21/189

Notes: OLS regression of the price equation in levels. Variables are defined in note to Table 4.

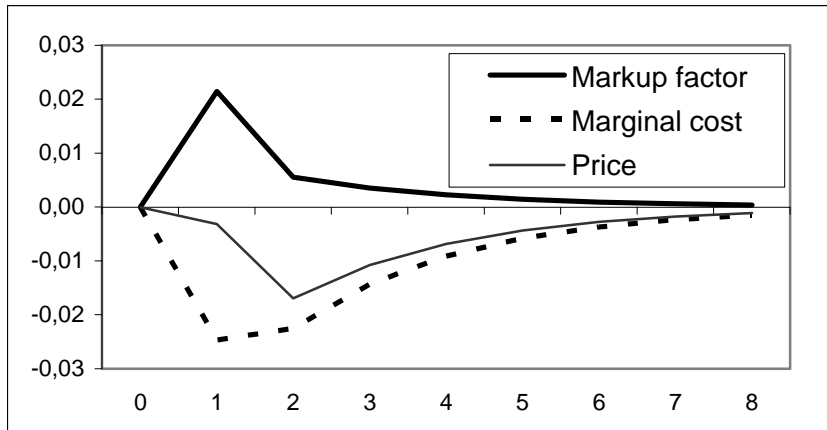
Regressions include individual-specific effects (at respective level of aggregation) and industry-specific time trends. ** and * denote 1 percent and 5 percent significance level respectively.

Figure 1. Effect of a 10 percent permanent decrease in demand ($\sigma\Delta y$) in $t=1$.

a) Production, investment and price

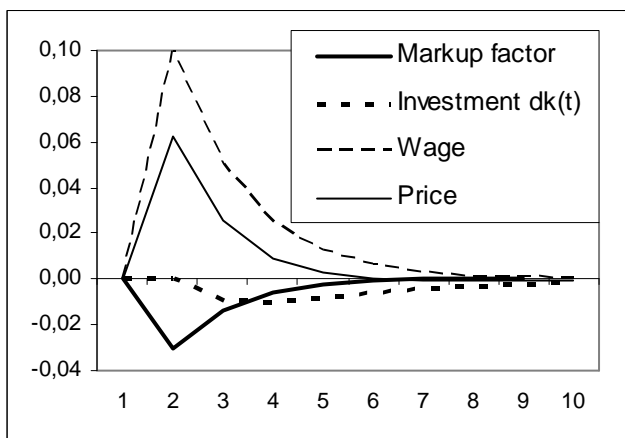


b) Price, marginal cost, and the markup



Note: The figure shows log deviations from steady state.

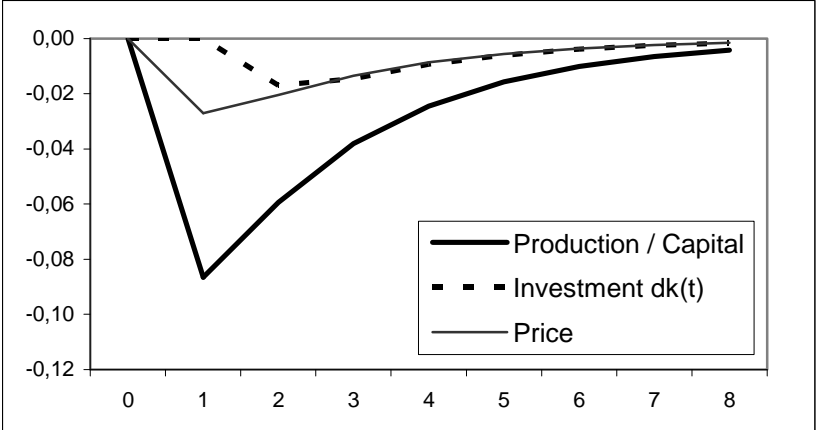
Figure 2. Effect of a 10 percent increase in the price of the flexible factor ($w-a-p^0$).



Note: The figure shows log deviations from steady state.

Figure 3. The effect of 10 percent decrease in demand without financial constraints ($\gamma=0$)

a) Production, investment, and price



Note: The figure shows log deviations from steady state.

b) Price, marginal cost, and the markup

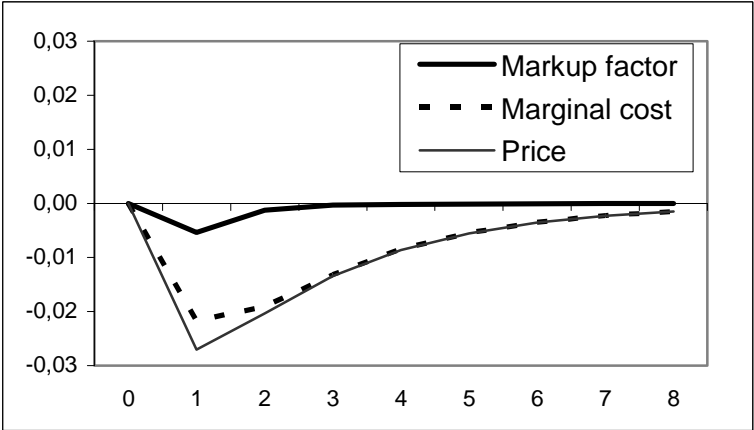
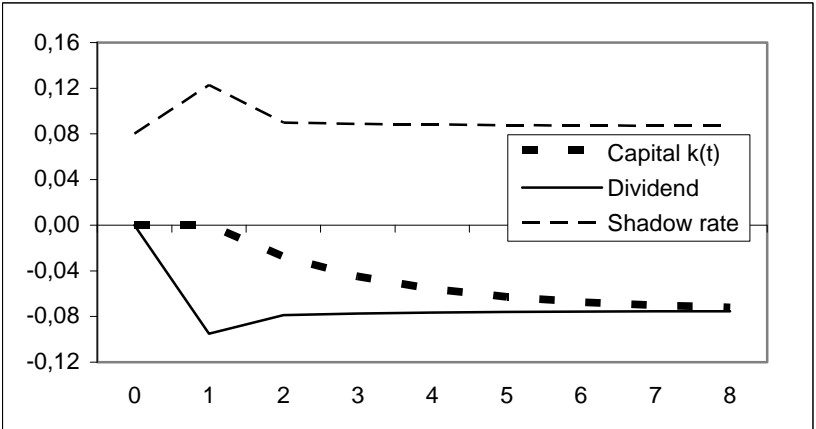


Figure 4. Dividends, capital stock, and shadow rate after a 10 percent decrease in demand in baseline case with $\gamma = 2$.



Note: Dividends and capital stock are measured as log deviations from initial value. Shadow rate is calculated as $D_t^{-\gamma} / (\beta D_{t+1}^{-\gamma}) - 1$. Parameters are set at baseline values.