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Capital Adjustment Patterns in Swedish Manufacturing Firms: What Model Do They Suggest?*

Mikael Carlsson and Stefan Laséen†

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Abstract

In this paper we study the capital adjustment process in Swedish manufacturing firms and relate the empirical findings to standard models of firm behavior in the presence of impediments to capital adjustments. We find that (i) an S, s model fits the data well in some, but not all, dimensions. (ii) A model with irreversible capital goes a long way in capturing the salient features of firm-level capital adjustment behavior. (iii) The partial adjustment model generally fails to explain capital adjustment patterns. (iv) The capital accumulation process is a highly volatile and non-persistent process on the firm-level. (v) Firms' adjustment behavior is asymmetric in that they are more likely to tolerate excess capital than shortages of capital, and, finally, (vi) the estimated adjustment function implies that aggregate investment is relatively unresponsive to aggregate shocks in deep recessions as compared to normal times.

JEL-Classification: E22; D24; L60
Keywords: Investment; Irreversibilities; Lumpiness; Manufacturing

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1 Introduction

In this paper, we study the capital adjustment process on firm-level data for the Swedish manufacturing industry and relate the empirical findings to standard models of firm behavior in the presence of adjustment impediments.

While most of the investment literature up to the 1990s focused on aggregate data, the empirical evidence on firm-level behavior is limited. Aggregate capital adjustment is generally found to be a smooth process, often captured by assuming that the representative firm faces convex adjustment costs. However, aggregation tends to smooth series and using aggregate data is likely to create an illusion of such adjustment behavior. Thus, it is not obvious that firm-level behavior can be inferred from studying aggregate data. In fact, recent work by, for example, Nielsen and Schiantarelli (1996) and Doms and Dunne (1998) supports the view that the capital adjustment process is far from smooth on the micro-level. Doms and Dunne (1998) examine a 17-year sample of large continuously operating U.S. manufacturing plants and find that the largest investment episode on average accounts for 25 percent of the cumulative investments of an establishment in the 17-year period. Moreover, half of the establishments experienced capital growth rates in the proximity of 50 percent in a single year. Nielsen and Schiantarelli (1996) study Norwegian micro-data and find that investment rates exceeding 20 percent only occur 10 percent of the time, but account for almost a third of total real investment expenditure. Thus, long periods of relatively small changes are interrupted by investment spikes. This has been widely interpreted as evidence of S, s-type behavior on the firm-level, i.e. that firms only invest when their actual capital stock deviates sufficiently from a target value, otherwise remaining inactive to avoid lump-sum adjustment costs.

A useful observation when thinking of firm-level adjustment behavior is that capital is rarely at its "desired" level when adjustment costs and/or irreversibilities are of any importance. The size of the capital adjustment depends on the type of adjustment cost the firm faces and the size of the deviation between the desired and the actual stock of capital. Since a firm's desired stock of capital is not easily measured, we approach the problem of characterizing the capital adjustment process from two directions. First, we make as few assumptions as possible regarding the measurability of the desired stock of capital, limiting ourselves to an assumption about the process governing the desired stock of capital. In the second part, on the other hand, we impose enough identifying assumptions to actually measure the desired stock of capital. Thus, the paper is divided into two parts.

Our main purpose in the first part is to portray the equipment and machinery capital adjustment patterns both within and between firms in continuously operating Swedish manufacturing firms over the period 1984-1994, without imposing a specific theoretical structure.[1,2] To relate this description to existing investment models, we generate hypothetical investment patterns for three alternative investment models, and compare these with the patterns in the data. We find that the capital adjustment process is indeed characterized by periods of high activity followed (and preceded) by periods of much lower activity. However, when studying these patterns more closely, it is no longer obvious that the results support the view that they have been generated by an S, s model. Instead, we find that a model where firms face irreversibility constraints goes a long way in capturing the salient features of firm-level capital adjustment behavior. To see this an integrated approach is necessary, since the alternative models do well in certain comparative dimensions, but less so in others.

In the second part of the paper, we apply a more direct approach and estimate an adjustment function relating capital adjustment to the difference between the actual and the desired capital stock. This difference is derived from the first-order conditions of a standard neoclassical model. In this part of the paper, we also examine the implications of our estimated adjustment function for aggregate capital adjustments.

Other findings of this paper, besides that discussed above, are that (i) partial adjustment behavior, due to convex adjustment costs, generally fails to explain capital adjustment patterns. (ii) The capital accumulation process is a highly volatile and non-persistent process

[1] Throughout the paper, we focus on equipment and machinery capital, since this type of capital is much less exposed to indivisibility constraints than structures, which forces firms to lumpy investment behavior. Henceforth, we will use the term capital synonymously with equipment and machinery capital.

[2] See Hansen and Lindberg (1997) for an Euler investment equation approach on firm-level data for the Swedish manufacturing industry.

on the firm-level. (iii) Firms' adjustment behavior is asymmetric in that they are more likely to tolerate excess capital than shortages of capital. (iv) The estimated adjustment function implies that the aggregate growth rate of capital is relatively unresponsive to aggregate shocks, e.g. a monetary policy shock, in deep recessions as compared to normal times.

This paper is organized as follows. Section 2 describes a stylized model of capital accumulation that allows for several types of firm-level behavior. Section 3 describes the data. Section 4 presents capital adjustment patterns and relate them to the predictions of three different investment models. Section 5 characterizes the micro-level adjustment behavior directly by estimating firm-level adjustment behavior. In section 6, we discuss implications for aggregation and section 7 concludes.

2 Model

Our starting point for modeling firm-level capital adjustment behavior is the observation that capital is rarely at its "desired" level when adjustment costs and/or irreversibilities are of any importance. To formalize this observation, we let the deviation between desired and actual capital before adjustment, i.e. mandated capital adjustment, be denoted:

$$m_{i,t} = k^*_{i,t} - k_{i,t-1}, \tag{1}$$

where $k^*_{i,t}$ and $k_{i,t-1}$ represent the natural log of desired and actual capital in firm i at time t. Positive values of m thus indicate capital shortage, whereas negative values reflect excess capital.

For a complete model of firm-level capital adjustment, we need two additional building blocks. First, we need to determine the desired stock of capital and second, we need an expression mapping adjustment incentives ($m_{i,t}$) to actual adjustment ($k_{i,t} - k_{i,t-1}$) - that is, the firms' adjustment behavior.

The Desired Stock of Capital

This section draws on Caballero, Engel and Haltiwanger (1995) and derives a measure of the desired capital stock. Let gross output be given by the following production function:

$$Y = AK^{\gamma}F^{\phi}, \ \gamma + \phi < 1, \tag{2}$$

where A is an index measuring technology, K is the stock of capital and F all other variable factors of production. It is assumed that only adjustment of the stock of capital is associated with adjustment costs - thus, all other variable factors, F, are flexible. Moreover, the production function is assumed to exhibit decreasing returns to scale. The profit is given by

$$\Pi = Y - P_F F - CK, \tag{3}$$

where P_F is the real price of flexible factors and C the real user cost of capital. Optimizing over flexible factors yields the following first-order condition:

$$F = \left(\frac{P_F}{AK^{\gamma}\phi}\right)^{\frac{1}{\phi-1}}. \tag{4}$$

Using (4), we can rewrite (2) as:

$$Y = \Psi K^{\frac{\gamma}{1-\phi}}, \tag{5}$$

where $\Psi = A^{1/(1-\phi)}\left(P_F/\phi\right)^{\phi/(\phi-1)}$. Using (5), the ratio of actual output to actual capital can be written as:

$$\frac{Y}{K} = \Psi K^{\frac{\gamma+\phi-1}{1-\phi}}. \tag{6}$$

Using (6), we obtain a useful expression for the actual stock of capital:

$$K = \left(\frac{Y}{K\Psi}\right)^{-\eta}, \tag{7}$$

where $\eta = (1-\phi)/(1-\gamma-\phi)$. We define frictionless capital as the stock of capital the firm would choose if it did not face adjustment costs. The first-order condition determining the frictionless stock of capital is given by:

$$\widetilde{K} = \left(\frac{C}{\gamma\Psi}\right)^{-\eta}, \tag{8}$$

where we have used (4) to eliminate flexible factors from the first-order condition for capital, and then solved for capital. Desired capital, on the other hand, corresponds to the stock of capital the firm would choose if the adjustment cost were temporarily removed. Following Caballero et al. (1995), we assume that the desired stock of capital, K^*, is proportional to the frictionless stock of capital, i.e.:[3]

$$K^* = d\widetilde{K}. \tag{9}$$

Note that the desired stock of capital is determined by the technology index, factor prices of flexible factors and the user cost of capital, which can all be reasonably well approximated as random walks with drift. For example, Dufwenberg, Koskenkylä and Södersten (1994) cannot reject the null that the user cost of capital is a random walk in Swedish data. Hence, it follows that the process for the desired stock of capital may also be modeled as a random walk with drift:

$$k^*_{i,t} = k^*_{i,t-1} + \xi_{i,t}, \qquad \xi_{i,t} \sim N\left[\mu, \sigma^2\right], \tag{10}$$

where the forcing process, $\xi_{i,t}$, is assumed to be *i.i.d* across firms and time.

Adjustment Behavior

We consider three standard models of firm level adjustment behavior. The first case is partial adjustment toward the desired stock of capital. In this case, the firm reduces the deviation between the desired and the actual stock of capital with a fraction, λ, each period,

$$k_{i,t} - k_{i,t-1} = \lambda m_{i,t}. \tag{11}$$

This type of gradual adjustment was often postulated in the early investment literature to account for the serial correlation of aggregate investment data. Later, micro foundations were provided for this kind of adjustment model by assuming that the firm faces symmetric convex adjustment costs (see e.g. Hamermesh and Pfann, 1996, for a survey).

[3] See Caballero et al. (1995) for a discussion of this assumption.

The second case we consider is lumpy capital adjustment behavior due to non-convex adjustment costs. The optimal capital adjustment behavior for a firm facing non-convex adjustment costs is captured by an S, s rule,

$$k_{i,t} - k_{i,t-1} = \begin{cases} m_{i,t} & \text{if} \quad m_{i,t} \geq U \text{ or } m_{i,t} \leq L \\ 0 & \text{if} \quad U > m_{i,t} > L \end{cases} . \tag{12}$$

That is, if the deviation between the desired capital stock in period t and the actual capital stock before adjustment, i.e. m, is larger (smaller) than or equal to a trigger level U (L), the firm will increase (decrease) its capital stock such that $m = 0$ after adjustment. On the other hand, if the value of m is between the upper, U, and the lower, L, trigger levels before adjustment, the firms' optimal behavior is to keep the level of the capital stock constant.

The third case is capital adjustment behavior when capital is completely irreversible, which would be the case if e.g. capital is firm specific and has no value on the second hand market. Under this restriction, Bertola and Caballero (1994) show that the optimal behavior is to fully adjust to the desired level of capital if the mandated capital adjustment is positive, and let capital depreciate towards the desired level if the mandated capital adjustment is negative,

$$k_{i,t} - k_{i,t-1} = \begin{cases} m_{i,t} & \text{if} \quad m_{i,t} > -\delta_i \\ -\delta_i & \text{if} \quad m_{i,t} \leq -\delta_i \end{cases} , \tag{13}$$

where δ_i is the depreciation rate.

In section 4 below, we will compare predictions from the three investment models to the patterns present in the data in several different dimensions. To this end, we simulate a panel of firms calibrated to correspond to the firms generating the real data set. We use (10) to generate the desired stock of capital. If we then apply the different adjustment rules (11), (12) or (13), we have a complete characterization of the capital adjustment process for our simulated panel of firms.

3 Data

The data we use consist of a balanced panel of ongoing manufacturing firms drawn from the CoSta database (described in Hansen, 1999).[4] This database is, in turn, based on Enterprises - Financial Accounts collected by Statistics Sweden, containing annual data for non-financial firms located in Sweden. Given the availability of data and after standard cleaning procedures, described in Appendix A, we are left with 341 firms observed over the period 1979 - 1994.

The capital stocks are estimated using the perpetual inventory method:

$$K_{i,t} = (1 - \delta_i)\, K_{i,t-1} + I_{i,t}, \tag{14}$$

where I is investments. Throughout the paper, investments are defined as real capital expenditures less the real market value of sold capital (see Appendix A for a detailed description of the variables used). As is evident from (14), this method requires an assumption about the initial value of the capital stock. We take the starting value from accounting data and we only use the years 1984-1994 in the analysis, to dampen the effect of this assumption. We will return to the plausibility of this initial assumption in the next section where we study the cyclicality of the growth rates of capital.

There obviously exist numerous ways of studying firm-level capital accumulation patterns. The measure of the growth rate of capital to be studied in the next section is defined for firm i at time t as:

$$GK_{i,t} = \frac{K_{i,t} - K_{i,t-1}}{K_{i,t-1}}. \tag{15}$$

This measure is a monotonic transformation of the measure used by Davis, Haltiwanger and Schuh (1997) and only differs by δ from the measure used by Nielsen and Schiantarelli (1996). That is, our measure implies that a zero growth rate of capital corresponds to an unchanged stock of capital.

[4] To check if our results are sensitive to the selection procedure, we present results from an unbalanced panel in Appendix D.

4 Firm-Level Capital Accumulation Patterns

In this section, we focus on capital adjustment patterns and relate these to the predictions of the stylized models of firm level adjustment behavior presented in section 2.

Ranking of Growth Rates

An informative way of assessing firms' adjustment behavior, without imposing any theory, is to rank the growth rates of capital for each firm from the highest to the lowest (see e.g. Doms and Dunne, 1998). Define $GK_i = \{GK_{i,t}\}_{t=1984}^{1994}$, $GK_i^1 = \max(GK_i)$ and $GK_i^j = \max\left(\left\{GK_i \backslash \left\{GK_i^k\right\}_{k=1}^{j-1}\right\}\right)$ for $j = 2, ..., 11$. The mean growth rate for the j^{th} largest growth rate is now given by

$$R^j = \frac{1}{n}\sum_i GK_i^j, \qquad j = 1, ..., 11. \tag{16}$$

Figure 1 presents these ranked growth rates.

The mean growth rate of capital for observations with rank 1 (R^1) is 0.57, which is twice as high as the second highest growth rate ($R^2 = 0.26$) and three times as high as the third highest growth rate ($R^3 = 0.17$). Thus, firms experience relatively few periods of large capital adjustment. This pattern is similar to what is found by e.g. Doms and Dunne (1998) and Nielsen and Schiantarelli (1996) and has been widely interpreted as evidence in favor of S, s behavior on the micro-level. However, as will be shown below, this interpretation is no longer obvious when we also consider irreversibility.

Simulated Growth Rates

To see what is implied by the different models of capital adjustment behavior, we investigate whether they can replicate the pattern observed in figure 1. We calibrate the models by minimizing the mean squared error (MSE) between the ranked capital adjustment rates, R^j, implied by the data and the simulated values, $R^j(\Theta)$ where Θ is the vector of parameters. Hence, Θ equals λ for the partial adjustment model, (U, L) for the S, s adjustment model, and $\varnothing$ in the irreversible adjustment model. The MSE is then given by

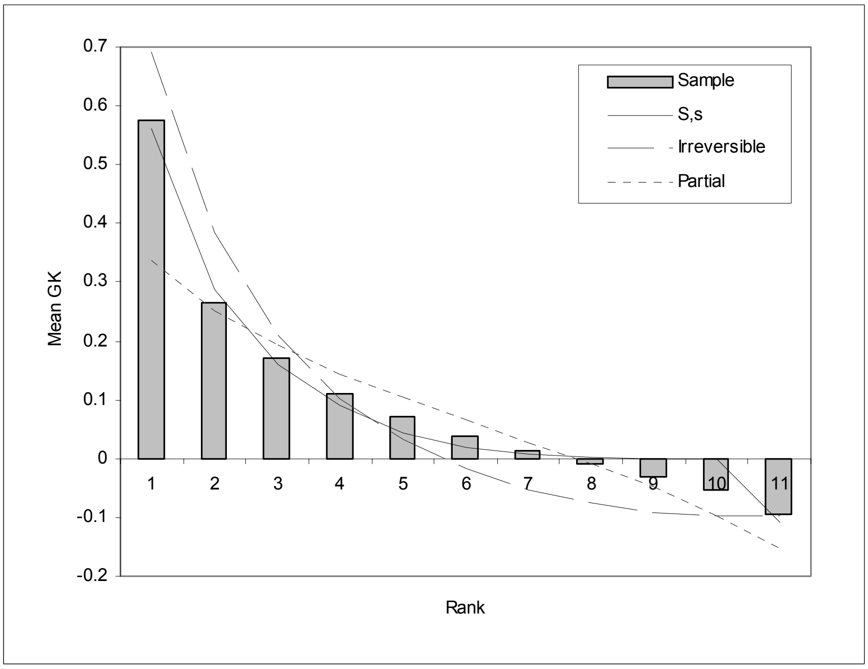

Figure 1: Mean growth rate of capital by rank (R^j) for the sample an the three simulated adjustment behaviors.

$$\mathrm{MSE}\left(\Theta\right) = \frac{1}{1-\mathrm{rank}\left(\Theta\right)} \sum_{j=1}^{11} \left(R^j - R^j\left(\Theta\right)\right)^2, \tag{17}$$

where $R^j\left(\Theta\right)$ has been generated from the three models above with the assumption that the desired stock of capital follows a random walk with drift – given by equation (10).[5]

The simulations are performed with $n = 341$ firms for $T = 300$ periods.[6] The simulated

[5] Since the model is expressed in log differences, we also express the data in log differences when minimizing the MSE. Then, we use the monotonic transformation, $GK_{i,t} = \exp(\ln(k_{i,t}/k_{i,t-1}))-1$, to compare the results of the simulation with the data in terms of percentage change. To minimize the MSE in the simulation with the S, s setup, we have utilized a grid search. The grid size was first set to 0.1. We then search on a finer grid ($\Delta 0.01$) around the optimal values (± 0.05) retrieved from the first coarser grid search. To minimize the MSE in the simulation with the convex adjustment costs, we used the Quasi-Newton minimization routine in Gauss 3.5. The model is similar to Doms and Dunne (1998). However, Doms and Dunne (1998) only analyze the S, s adjustment rule.

[6] The number of firms is chosen to match our panel, the depreciation rates are set to have the same values

growth rates of capital, $GK_{i,t}(\Theta)$, are calculated for the last 11 periods ($t = 290, 291, .., 300$) and ranked as was done with the real data in equation (16). A problem when calibrating the model is to pin down the mean and standard deviation of the forcing process in equation (10). For this purpose, we construct a measure of the firm's desired capital stock (described in section 5). Using this measure, our data suggest that the mean and the standard deviation of the forcing process equal 0.049 and 0.378, respectively. This value of σ is higher than that used by Doms and Dunne (1998) for the U.S. economy ($\sigma = 0.18$). An explanation for this finding might be that Swedish firms are more exposed to international conditions than what is the case for firms in the U.S.

The first simulation introduces partial adjustment behavior. The λ, i.e. the fraction of m that is closed in each period, that minimizes the MSE equals 0.35. The corresponding MSE is 0.0073. It is evident from figure 1 that partial adjustment does not succeed in capturing the salient features of the data. Most importantly, the partial adjustment model cannot reproduce the sharp drop in growth rates we see in the data after the first rank. The mean growth rate is 0.34 for rank 1 and 0.25 for rank 2. The partial adjustment model implies symmetric capital adjustments, which does not seem to be a fair approximation of actual adjustment behavior.

The second simulation is made with the S, s adjustment model. It is obvious that the S, s model provides an improvement relative to the partial adjustment model. The main feature of this simulation is how the simulated values can track the sharp fall in the growth rates of capital in the data after the first rank. The observed growth rates of capital are slightly higher for intermediate ranks and lower for ranks 8 to 10 than what we can reproduce with the S, s model. The trigger levels, expressed in the log difference space, that minimize the MSE at 0.000713 are $U = 0.02$ and $L = -2.07$. Thus, the firm will adjust its capital stock up to its desired stock, if the desired level is 1.02 times larger than the actual stock of capital. Analogously, the lower trigger level implies that the firm will adjust its capital stock down to the desired level if the actual stock is 7.92 times larger than the desired stock. It should

and distribution as the firms in the panel and the number of periods is chosen to ensure that the initial conditions are irrelevant.

be noted that the optimal S, s behavior then implies that we should only observe negative adjustments exceeding -87 percent, whereas the largest negative adjustment in the sample is -53 percent. It is interesting to see that the trigger levels minimizing the MSE come very close to what one would set them to in order to mimic an irreversibility constraint as close as possible with the S, s model. That is set U to zero and L to a very low value.[7]

Given the results of the S, s model, it is not surprising that the irreversibility model turns out to yield a similar adjustment pattern. Apart from ranks 4 and 11, the S, s model does a better job for all ranks, however. The mean growth rate levels off at approximately -10 percent, which is what should be expected since the mean rate of depreciation almost equals 10 percent. Remember that when capital is completely irreversible, the stock of capital can only be reduced by being allowed to depreciate, which implies that the growth rate for rank 11 should be close to the mean rate of depreciation. Although there are observations of GK in the sample that are lower than the depreciation rate, something we should not observe if capital is completely irreversible, these only constitute four percent of the total number of observations in the sample.

Finally, when comparing the MSE:s, we see that the MSE for the irreversible setup (0.00543) is about 74 percent of the MSE for the partial adjustment model (0.0073). However, the MSE of the S, s model (0.000713) is only about 13 percent of the MSE of the irreversibility setup. The conclusion from this section is that the S, s model fits the patterns in the data best, followed by the irreversibility model. However, it is interesting to see that the S, s model accomplishes this by setting the trigger levels as if to mimic an irreversibility constraint.

Within-Firm Timing Pattern of Capital Adjustment

Another interesting and informative aspect of the capital adjustment process is the within-firm timing patterns of capital adjustment. More specifically, we are interested in what happens to the growth rates in the years preceding and following upon the year with the highest growth rate. To calculate these growth rates, define $GK^1_{i,t-1}$ to be the growth

[7] Note that the irreversible model is not a special case of the S, s model; in the S, s model we have assumed that if the firm allows the capital stock to depreciate, it must pay a fixed adjustment cost.

rate for firm i the year before the year with the highest growth rate. We can now define

$$R^1_{t+l} = \frac{1}{n}\sum_i GK^1_{i,t+l}, \qquad l = -2, -1, .., 2. \tag{18}$$

The mean growth rate across firms one year before the year with the highest growth rate is, consequently, denoted R^1_{t-1}. Figure 2 depicts $R^1_{t-2}, R^1_{t-1}, R^1_t, R^1_{t+1}$and R^1_{t+2}. It is evident that large capital adjustments do not seem to be preceded or followed by large capital adjustments, as would be expected if firms followed some smooth adjustment rule. Instead, the timing pattern indicates that capital adjustments are, to a large extent, performed in bursts.[8] Thus, we see no signs of the smooth behavior found on the aggregate level when studying firm-level data.

What implications do the different adjustment models have for the within-firm timing patterns of capital adjustment? To shed some light on this issue, we calculated the mean growth rates of capital surrounding the maximum capital growth rate for the simulated data. Figure 2 depicts these rates for the partial adjustment, the S, s and the irreversible model together with the growth rate for the real data. Once more, the simulated timing patterns for the partial adjustment model cannot reproduce the pattern we see in the data. Instead, this model implies a gradual build-up of a large deviation in m before the rank 1 observation, followed by a gradual reduction in this deviation. The timing pattern in the data is much more in line with the S, s or irreversible investment models where firms are at a much lower level of investment spending before and after an investment spike. This is natural, since both these models imply that there should be no persistence in positive capital adjustments.

The conclusion from this section is that the timing pattern in the data seems to be almost equally well described by the S, s and the irreversibility model, whereas the partial adjustment model is unable to reproduce the timing pattern in the data.

[8] In appendix C, we show that the rank and the timing patterns are similar across firms of different size. Thus, the results cannot be argued to be driven by a large number of small firms, restricted by indivisibility constraints in their adjustment behavior.

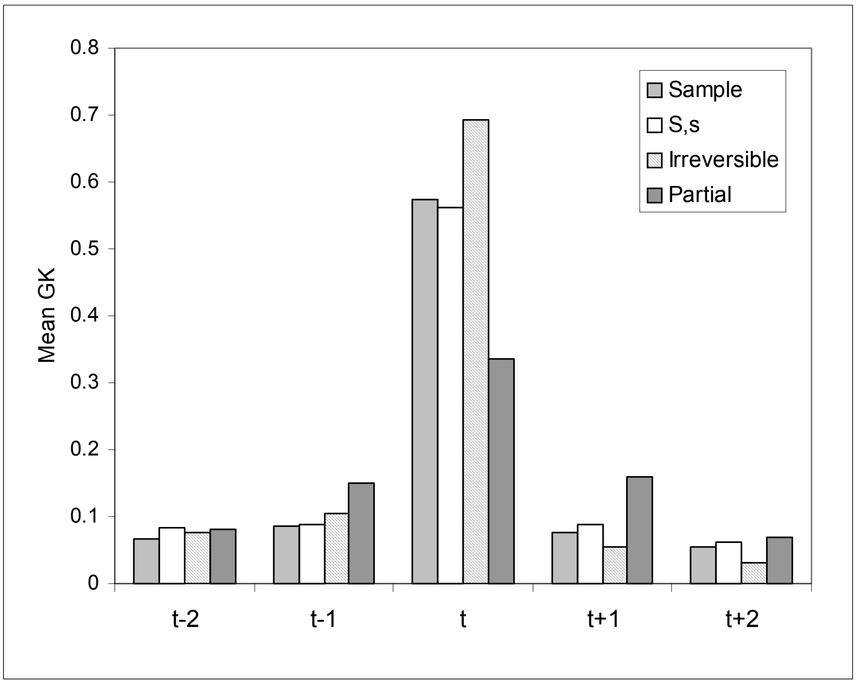

Figure 2: Mean growth rate of capital for the years surrounding rank 1 (R^1_{t+l} where $l = -2, -1, .., 2$) for the sample and the simulated adjustment models.

Distribution of Growth Rates

The density of the growth rates of capital is plotted in figure 3 (top left-hand panel).[9] The distribution is skewed to the positive side and indicates a large portion of relatively large positive capital adjustments. The negative adjustments seem to be few and relatively small, however. A large portion of the observations are bunched up around zero. However, it is hard to detect any other attractors in the distribution. A concern when focusing on ongoing firms is sample selection. When selecting ongoing firms, we might only select firms with small negative adjustments - thereby biasing the results towards finding irreversibility. However, the distribution of the corresponding unbalanced panel, presented in Appendix E, is very similar to the distribution of the balanced panel,[10] thereby suggesting that the sample

[9]Besides a zero line, we have also included a line at -0.1375, which is the negative of the highest rate of depreciation in our sample.

[10]The unbalanced panel corresponds to a sample of 2321 firms observed in at least seven consecutive

selection problem is not a crucial issue here.

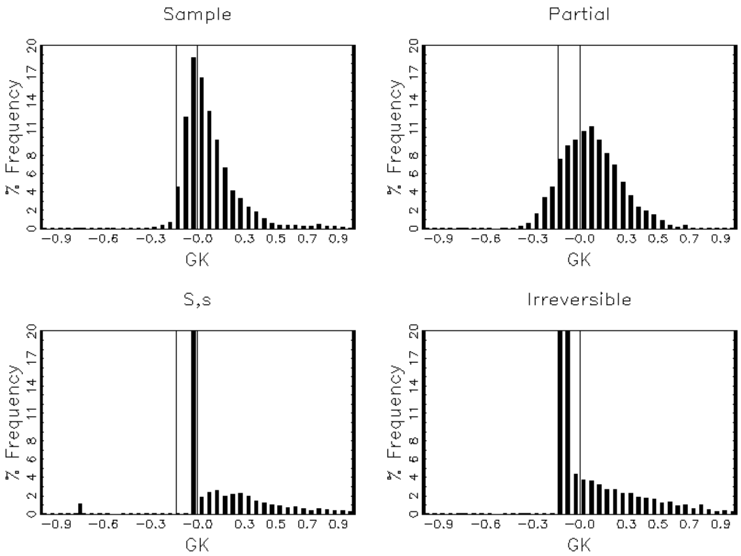

Figure 3: Density of the growth rates of capital for the sample and for the three cases of simulated adjustment behavior.

The corresponding distributions of the simulations are presented in the other panels of figure 3. The partial adjustment model (upper right panel) gives rise to a distribution that is much more symmetric than the real data. The S, s model (the lower left-hand panel) predicts that there should be a large mass of observations at zero, due to the assumption that there is a fixed cost in adjusting the level of capital. Note also the spike right below -0.9 which is due to negative capital adjustment. These large negative adjustments are not a feature of the real data, however, whereas small negative adjustments do occur. The results for the irreversible case are presented in the lower right-hand panel. As expected, the observations bunch up against minus the depreciation rate, since this is the only way of alleviating negative deviations between the desired and the actual capital stock. Overall, we

periods. This sample is drawn from the same data as the balanced panel and obtained using the same cleaning procedures as the balanced panel. After calculating the capital stocks by the perpetual inventory method (the reason why we need a series of consecutive observations), we drop the first four observations to dampen the effects of the initial condition.

find the results presented in figure 3 to be suggestive of irreversibility as being a prominent feature of the data.

Cyclical Movements in Growth Rates

Figure 4 shows a decomposition of the aggregate growth rate of capital in the sample by rank, where the sample aggregate growth rate year t is defined as:

$$GK_{A,t} = \sum_i \omega_{i,t} \frac{(K_{i,t} - K_{i,t-1})}{K_{i,t-1}}, \tag{19}$$

with the weights defined as $\omega_{i,t} = K_{i,t-1}/\sum_i K_{i,t-1}$. The figure conveys that fluctuations in the aggregate growth rate of capital are mainly accounted for by ranks 1 and 2. In fact, the growth rate of rank 1 accounted for the total growth rate in the recession years 1992 to 1994. Thus, the contribution of ranks 2 to 11 to the aggregate growth rate cancel out. Moreover, only about four percent of the firms (approximately 14 firms) per year were assigned rank 1 during this period, as can be seen in figure 5. Hence, large capital adjustments of relatively few firms seem to be an important determinant of aggregate changes.

Figure 5 shows the share of firms in the sample with ranks 1, 2, 10 and 11 for each year. The figure clearly reflects the negative effect of the recession on the share of firms with low ranks in the early 1990s, as well as the favorable effect of the recovery in 1994.[11] In Appendix D, we show that the rank and timing patterns in investments are similar to the corresponding capital growth rate patterns. Thus, supporting that the results are not due to our assumption about how the capital stock evolves over time.

[11] Another relevant aspect of figure (5) is that the share of firms with rank 1 increases from 1984 to 1985 and is relatively stable throughout the 1980s. This would not have been the case if the starting value, $K_{i,1979}$, used in the perpetual inventory formula, (14) had been too low. A priori, one would suspect the starting value taken from accounting data of being too low. This is the case since measures of the stock of capital taken from accounting data are only stated in nominal terms. Thus, investment goods inflation implies that older vintages of capital will be underestimated when the current value of the stock is deflated with the current value of the investment deflator.

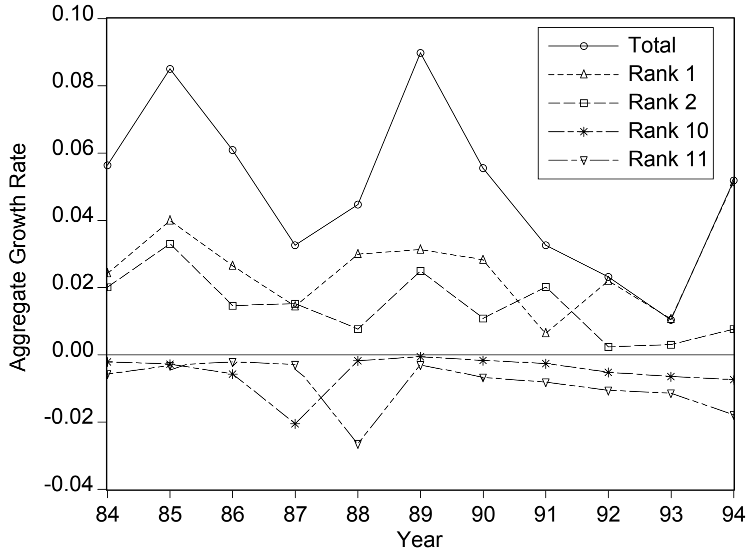

Figure 4: Aggregate growth rate of capital and the weighted growth rates of ranks 1, 2, 10 and 11.

5 Firm-Level Adjustment Behavior

In this section, we take a somewhat more direct approach to characterizing micro-level adjustment behavior. That is, here we estimate the function describing how the firm reacts to deviations between the desired and the actual stock of capital before adjustment, i.e. $m_{i,t}$. To derive a measure of $m_{i,t}$, we can use the desired capital stock, equation (9), and the actual capital stock, equation (7), derived in section 2. The ratio of (9) and (7) yields the following expression

$$\frac{K^*}{K} = d\left(\frac{C}{\gamma\Psi}\right)^{-\eta}\left(\frac{Y}{K\Psi}\right)^{\eta}. \tag{20}$$

Taking the log of (20) on both sides and collecting terms yields:

$$k^* - k = \eta\left[y - k - c + \ln\gamma + \frac{\ln d}{\eta}\right], \tag{21}$$

where lower case letters denote the log of the variable. Since we seek an expression for the gap between the desired and the actual stock of capital before adjustment (mandated capital

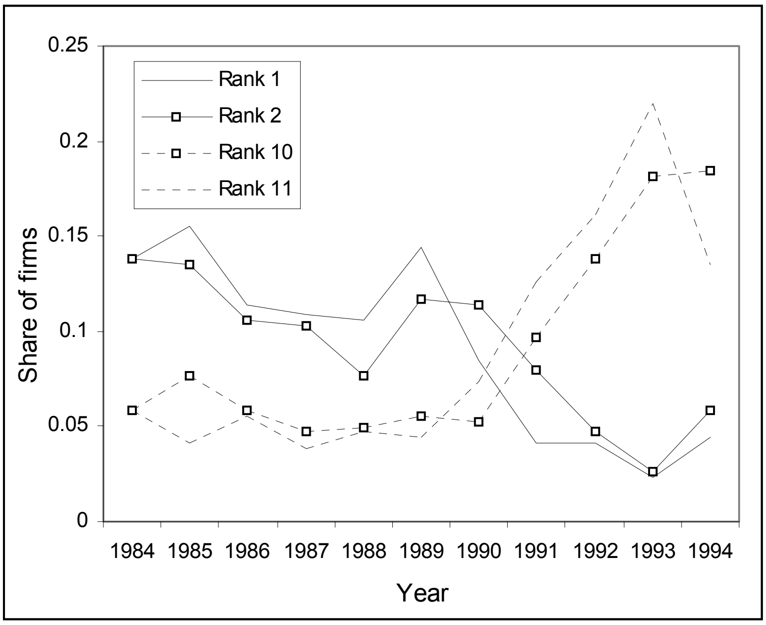

Figure 5: Share of firms in the sample with ranks 1, 2, 10 and 11 for each year.

adjustment) we need to make an assumption about the timing. The following assumptions are made: first, the firm produces its output with the capital stock in period $t-1$. This is a reasonable assumption because the installation of new capital goods should be time consuming and the stock of capital is measured at the end of the period. Second, the timing within each period is as follows: first, shocks are realized; second, adjustments are made; third, production takes place; and finally, capital adjustments become productive. Since production takes place with the stock of capital lagged one period, what is of importance for the firm when deciding upon the size of the capital adjustment is the expectation of the conditions in period $t+1$ in t. Under the assumption that the determinants of $\widetilde{k}$ follow random walks with drift, the mandated capital adjustment for firm i can be written as:

$$m_{i,t} = k'_{i,t} - k_{i,t-1} = \eta_i \left[y_{i,t} - k_{i,t-1} - c_{i,t} + v_i \right], \tag{22}$$

where $k'_{i,t} = k^*_{i,t} + \kappa_i$ and v_i denotes the sum of the constant terms, including κ_i/η_i. Finally, we follow Caballero et al. (1995) and approximate η_i by $1/(1-\alpha_i)$, where α_i is the cost share of equipment capital in total revenue. Intuitively, expression (22) implies that the deviation between the desired and the actual stock of capital is proportional to the imbalance in the standard Jorgensonian (Neoclassical) first-order condition for capital.

To estimate the mandated capital adjustment from (22), we only need to obtain estimates of the firm-specific constants, υ_i. To this end, we make use of the fact that the firm will eventually eliminate deviations between the desired and the actual stock of capital. Hence, the mandated capital adjustment will be zero in the long run. This, in turn, implies that the error term, $\varepsilon_{i,t}$, will be stationary in the following equation:[12]

$$k_{i,t-1} - y_{i,t} + c_{i,t} = \upsilon_i + \varepsilon_{i,t}. \tag{23}$$

The constants, υ_i, can thus be consistently estimated with OLS. Using this estimate of the constants, we can back-out the mandated capital adjustment from (22). As a final step, the measure of mandated capital adjustment is expressed as a deviation in percentages (denoted by superscript p) instead of a log deviation.[13]

Given that the irreversible and the S, s models of capital adjustment behavior imply that the adjustment function relating actual adjustment to mandated capital adjustment, i.e.:

$$GK_{i,t} = f(m^p_{i,t}), \tag{24}$$

might not be well behaved and since we want to describe capital adjustment without imposing a specific theoretical structure, we apply a non-parametric approach to estimation. More specifically, we take the averages of actual adjustment, $GK_{i,t}$, over nine intervals defined on $m^p_{i,t} \in [-0.8, 1]$.[14]

[12] We have also estimated mandated capital adjustment by running the following cointegration regression: $k_{i,t-1} - y_{i,t} = \upsilon_i + \theta c_{i,t} + \varepsilon_{i,t}$. This procedure yields an estimate of $\theta = -0.63$ with a standard error of 0.02. Using this estimate of θ together with the estimates of the constants from this regression does not qualitatively change the results in the present and the following section. We also experimented with including lagged differences of the cost of capital, as suggested by Caballero (1994), to mitigate the small sample attenuation bias present in this type of cointegrating regressions. However, this did not bring our estimate of θ any closer to its theoretical value of minus unity.

[13] For this purpose, we use the following transformation $m^P_{i,t} = (K'_{i,t} - K_{i,t-1})/K_{i,t-1} = e^{m_{i,t}} - 1$.

[14] The function thus corresponds to a partition of $m^p_{i,t}$ into 9 intervals between -0.8 to 1. The interval between -0.8 and 1 includes 96 percent of the observations on $m^p_{i,t}$.

The resulting average adjustment function is depicted in figure 6, where the mean of each interval has been joined together. There are several interesting aspects of the empirical adjustment function First, the function is clearly upward sloping, supporting the notion that the approach does capture investment incentives. On average, the largest positive capital adjustment takes place when mandated capital adjustment is at its highest. Second, the function is suggestive of an asymmetric response to capital surpluses and capital shortages. That is, on average, firms seem to be less responsive to capital surpluses relative to capital shortages. In figure 6, we have also plotted the distribution of mandated capital adjustment, which indicates that the mass of observation is well captured by the interval -0.8 to 1. Moreover, the distribution indicates that the asymmetry between positive and negative mandated adjustments takes place where there is a high density of observations.

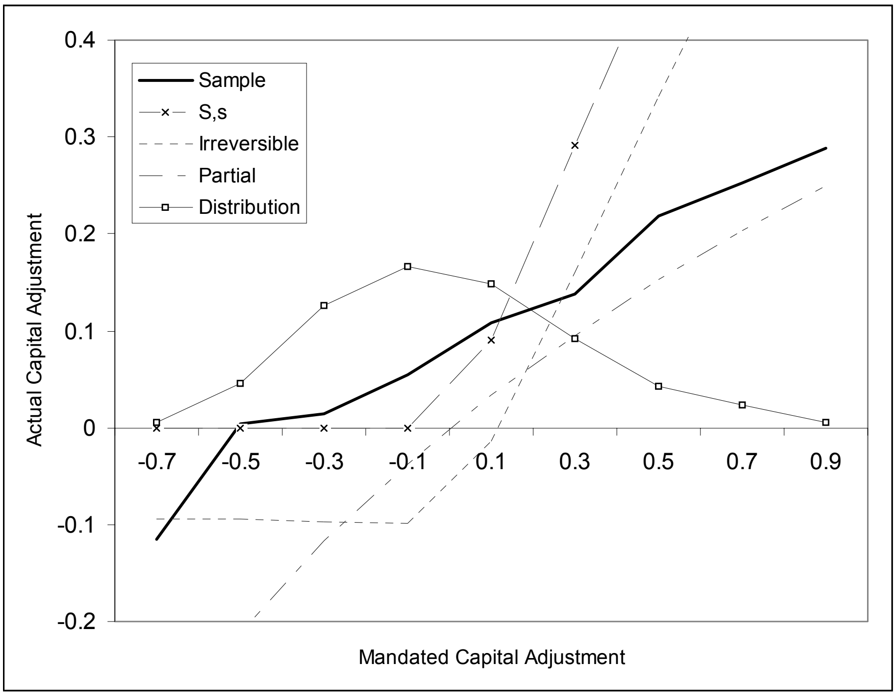

Figure 6: Empirical and simulated adjustment function, i.e. the averages of actual adjustment, $GK_{i,t}$, over nine intervals defined on $m^p \in [-0.8, 1]$.

Next, we compare the empirical adjustment function, obtained by the non-parametric approach, to what is implied by the simulation of different capital adjustment models. The empirical adjustment function implies that the firms are relatively unresponsive to negative deviations, as predicted by irreversibility. The estimated S, s rule also implies that the firm should not react to negative deviations in the interval, presented in figure 6. However, the S, s model, fitted above, suggests that when adjusting, the firms should react with a large negative adjustment. Such large negative capital adjustments are not present in the data (see section 4), suggesting that the irreversibility model provides a better description of firm behavior when mandated capital adjustment is negative. On the positive side, we see that the empirical adjustment function seems to be flatter than implied by any of the adjustment models studied in this paper. This might be due to measurement errors in our measure of mandated capital investments.[15] These errors would then attenuate the slope of the estimate adjustment function. In Appendix E, we experiment with lagged mandated capital adjustments as instrument to control for classical measurement errors. Although this produces a much steeper adjustment function, it does not qualitatively change the results. Moreover, the instrument used, i.e. the lag of m_i, is questionable if the true adjustment function is non-linear (see Appendix E for a discussion).

The first impression of the results in this section is that none of our candidates (partial, irreversible or S, s adjustment model) can fully explain the observed behavior. Nevertheless, the overall conclusion is that firms seem to be less responsive to capital surpluses relative to capital shortages, which cannot be explained by a partial adjustment model.

6 Implications for Aggregate Investment

Are the results from the previous sections important for understanding aggregate investment? To analyze this, we start by approximating the empirical adjustment function by a polynomial:

$$GK_{A,t} = \sum_i \omega_{i,t} \left[a_0 + \sum_j a_j \left(m^p_{i,t}\right)^j\right], \tag{25}$$

where we have used (24) and (19). In a world without frictions $a_1 = 1$, and for the partial adjustment model $a_1 \in (0,1)$ with $a_j = 0 \ \forall j > 1$ in both cases. Now, consider the effect

[15] Another explanation might be financial constraints, which we do not consider in this paper.

of an aggregate shock shifting the distribution of mandated adjustment to the positive side, while preserving the shape of the distribution. An important implication of the two special cases mentioned above is that the response of aggregate capital accumulation to an aggregate shock is independent of the distribution of mandated capital adjustment across firms since:

$$\sum_i \frac{\partial GK_{A,t}}{\partial m_{i,t}^p} = a_1, \tag{26}$$

where the derivative measures the composite effect of an increment in each firm's mandated capital adjustment on the aggregate growth rate of capital. However, if the adjustment function is non-linear, as is the case for the S, s or the irreversible model, the responsiveness to aggregate shocks will also depend on the cross section of mandated capital adjustment, i.e.:

$$\sum_i \frac{\partial GK_{A,t}}{\partial m_{i,t}^p} = \sum_i \omega_{i,t} \left[a_1 + \sum_{j=2}^{N} a_j j \left(m_{i,t}^p \right)^{j-1} \right]. \tag{27}$$

Hence, the response of aggregate accumulation to an aggregate shock will be determined by the shape of the distribution of $m_{i,t}^p$ across firms (i.e. higher-order moments than the first).

To empirically assess the importance of movements in the cross section of $m_{i,t}^p$ for determining the aggregate growth rate of capital, we take the following approach: first, we estimate the parameters of the polynomial approximation and use these estimates to evaluate (27) at the distribution of $m_{i,t}^p$ for each year in the sample.[16] Second, we compare the results from the first step to the derivative (26), obtained by restricting $a_j = 0 \; \forall \; j > 1$ when estimating the polynomial approximation. Since we have relatively few observation for $m^p > 1$ and hence, limited information on the shape of the adjustment function beyond this level, we restrict the attention to firms with a mandated capital adjustment within -0.8 to 1 throughout the sample period 1984-1994, leaving us with a sample of 233 firms.[17]

In figure 7, the responsiveness for aggregate capital growth to aggregate shocks is depicted by year.

[16] The parameters of the polynomial approximation are estimated by fitting a high-order polynomial to the nine points of the empirical adjustment function.

[17] The correlation between the aggregate growth rate of capital for this subsample, and the same measure for the balanced panel, amounts to 0.89.

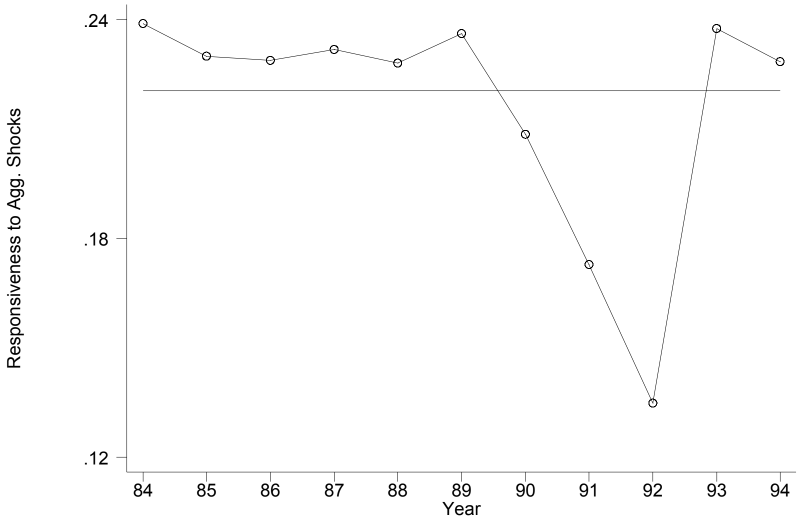

Figure 7: Responsiveness of aggregate capital growth to aggregate shocks.

Thus, if the adjustment function had been linear, a one percentage unit increase in the mandated capital adjustment of all firms would increase the aggregate growth rate of capital by about 0.22 percentage units, illustrated by the straight line in figure 7. However, allowing for nonlinearity in the adjustment function has an important effect for the responsiveness of aggregate capital growth to aggregate shocks in times of low economic activity. In the midst of the recession at the beginning of the 1990s, the responsiveness was only about half of its average in normal times (0.13). The intuition for this is that the distribution of firms' mandated capital adjustments is centered at the flat part of the adjustment function in this period. In this region of the adjustment function, firms are unwilling to respond to changes in investment incentives, due to e.g. binding irreversibility constraints. An implication is e.g. that monetary policy seems to be relatively powerless in stimulating the economy during recessions, whereas it can effectively cool off an overheated economy.

7 Conclusions

The objective of this paper was to present a series of stylized facts on the capital accumulation patterns for Swedish manufacturing firms and relate the empirical findings to standard models of firm behavior in the presence of impediments to capital adjustments. To this end, we use an integrated approach, i.e. we compare the predictions of different investment models to the observed patterns in the data both within (rank and timing patterns of the growth rate of capital) and between (distribution of the growth rate of capital) firms. Furthermore, we also apply a more direct approach and estimate an adjustment function relating capital adjustment to the difference between the desired and the actual capital stock.

We show that the partial adjustment model generally fails to explain capital adjustment patterns and that an S, s model only succeeds in replicating the stylized features of the data within, but not between, firms. The trigger points of the simulated S, s model suggest firms' adjustment behavior to be asymmetric in that they are more likely to tolerate excess capital than shortages of capital. Moreover, it is interesting to see that the trigger levels are close to where one would set them to in order to mimic an irreversibility constraint. However, the irreversibility model yields an adjustment pattern similar to the S, s model in the within-firm dimension, but not in the between-firm dimension, where it fits the data better than the S, s model. We also decompose the cyclical pattern of growth rates of capital and find that large capital adjustments in relatively few firms seem to be an important determinant of aggregate changes.

In the second part of the paper, we show the estimated adjustment function to be upward sloping, supporting the notion that the approach does capture investment incentives. The adjustment function suggests an asymmetric response to capital surpluses and shortages; on average, firms seem to be less responsive to capital surpluses relative to capital shortages. When we connect the first and the second part of the paper by relating the empirical adjustment function to the adjustment functions implied by the standard models of firm behavior, we find that irreversibility seems to provide a better description of firm behavior, when the mandated capital adjustment is negative. For positive values, we see that the empirical adjustment function is flatter than implied by any of the adjustment models studied in this paper. This may be due to measurement errors or financial constraints.

We close the paper by examining whether the results from the previous sections are important for our understanding of the behavior of aggregate capital accumulation. The results indicate that not allowing for nonlinearity in the adjustment function, i.e. assuming convex adjustment costs, would be misleading. We find especially large effects of nonlinearity on the responsiveness of aggregate capital growth in times of low economic activity. In the midst of the recession at the beginning of the 1990s, the responsiveness was only about half its average in normal times.

The overall conclusion is that none of the models are perfect in the sense that they could reproduce the patterns in the data in all dimensions studied, but a clear element of irreversibility is found in the data. A policy implication from this is that monetary policy seems to be relatively powerless in stimulating the economy during recessions, whereas it can effectively cool off an overheated economy.

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A Data

The data used in this paper are extracted from the CoSta database, described in Hansen (1999). The sample of firms was first selected as follows:

- Only firms classified within industries 31-38 according to the SNI69 classification system, i.e. the manufacturing sector, are included.
- Only firms that are ongoing throughout the sample period are included (to obtain a balanced panel).
- Only firms classified as an ordinary company and as an identical/comparable firm from the previous year in all years are included.

The variables are defined below in terms of those in the CoSta database (see Hansen 1999).

Output $Y_{i,t} = Var005_{i,t}/PPI_{i,t}$, where $Var005$ is operating income and PPI is a three-digit industry-specific producer price index supplied by Statistics Sweden. For industries where a three-digit producer price index is missing, a two-digit producer price index is instead used.

The **Stock of Capital** $K_{i,t}$ is the stock of machinery and equipment generated using the perpetual inventory method, i.e.:

$$K_{i,t} = (1 - \delta_i)K_{i,t-1} + I_{i,t}, \tag{28}$$

where δ_i is the depreciation rate and $I_{i,t}$ investments in machinery and equipment. When calculating three-digit depreciation rates for machinery and equipment, the estimated industry-specific service lives (SL_i) are taken from the BEA publication "Fixed Reproducible Tangible Wealth In the United States, 1925-89" and the estimated declining balance rate (DBR) for machinery and equipment, assumed to be equal for all manufacturing industries (1.65), is taken from the BEA publication "Improved Estimates of Fixed Reproducible Tangible Wealth, 1929-1995" by Katz and Herman (1997). The depreciation rate is then calculated as $\delta_i = DBR/SL_i$. Unfortunately, in most cases, we must resort to an estimate of the service life for two-digit industries. Investments are defined as $I_{i,t} = (Var115_{i,t} + Var119_{i,t} - Var127_{i,t})/IPI_{i,t}$, where IPI is the two-digit investment deflator compiled from investment series for machinery and equipment in current and fixed prices, collected from SM series N, Statistics Sweden. The value according to the plan of machinery and equipment ($Var146_{i,1979}$) deflated by $IPI_{i,1979}$ is used as starting value for the stock of capital.

The **Real User Cost of Capital** $C_{i,t}$ is defined as in Dufwenberg et al. (1994), i.e.:

$$C_{i,t} = \frac{IPI_{i,t}}{PPI_{i,t}} \left(\frac{1 - \Theta_t}{1 - \tau_t} \right) \left(\rho_t + \delta_i - \frac{\Delta IPI_{i,t}}{IPI_{i,t-1}} \right), \tag{29}$$

where τ_t is the corporate tax rate, ρ_t is the firms' discount rate (assuming a debt to capital ratio of 0.4 and the shareholders' required rate of return after tax is equal to 1.5 times the yield on long-term industrial bonds) and Θ_t is the present discounted value of tax savings from depreciation allowances, investment grants, etc. per unit of investment. The series for τ_t, ρ_t and Θ_t have kindly been provided by Jan Södersten.

For the firm to be included in the sample, we also require it to have a stock of capital, capital expenditures, i.e. $(Var115_{i,t} + Var119_{i,t})$, and a market value of sold machinery and equipment, i.e. $Var127$, that are non-negative in all time periods. This leaves us with a sample of 341 firms.

B Results from Size Quartiles

To study whether the size of the firm is an important determinant for the shape of the capital adjustment pattern, e.g. due to indivisibility, we split the sample into size quartiles on basis of the average number of employees.[18] We use the average number of employees over the years 1979-1982 as a criterion of separation. The pattern in tables 1 and 2 is consistent with the indivisibility argument, i.e. small firms are forced to discrete adjustments. However, all quartiles share the same general pattern.

Table 1: Mean GK for employment size quartiles

Rank	Q1	Q2	Q3	Q4	Total
1	0.6904	0.6192	0.5151	0.4681	0.5741
2	0.2981	0.2853	0.2624	0.2117	0.2646
3	0.1821	0.1884	0.1686	0.1399	0.1700
4	0.1091	0.1205	0.1077	0.0971	0.1088
5	0.0657	0.0778	0.0727	0.0642	0.0702
6	0.0274	0.0435	0.0455	0.0381	0.0387
7	0.0258	0.0204	0.0175	0.0119	0.0132
8	-0.0203	-0.0061	-0.0074	-0.0029	-0.0091
9	-0.0428	-0.0315	-0.0266	-0.0219	-0.0307
10	-0.0664	-0.055	-0.0471	-0.0465	-0.0538
11	-0.1061	-0.0935	-0.0907	-0.0880	-0.0946

Table 2: Mean within firm timing pattern (mean GK)

	$t-2$	$t-1$	t	$t+1$	$t+2$
Q1	0.0746	0.0718	0.6904	0.0571	0.0714
Q2	0.0780	0.1106	0.6192	0.0782	0.0419
Q3	0.0625	0.102	0.5151	0.0903	0.0589
Q4	0.0480	0.0574	0.4681	0.0752	0.0491
Total	0.0658	0.0859	0.5741	0.0755	0.0549

[18] Q1: n (the average number of employees) ≤ 58, Q2: $58 < n \leq 89.4$, Q3: $89.4 < n \leq 178.2$, Q4: $n > 178.2$.

C Investment Patterns

Since the growth rates of capital studied above involve at least two assumptions, it is interesting to study the capital adjustment behavior in the investment dimension. In figure 8, we have plotted the mean shares of total 11-year investment by rank.

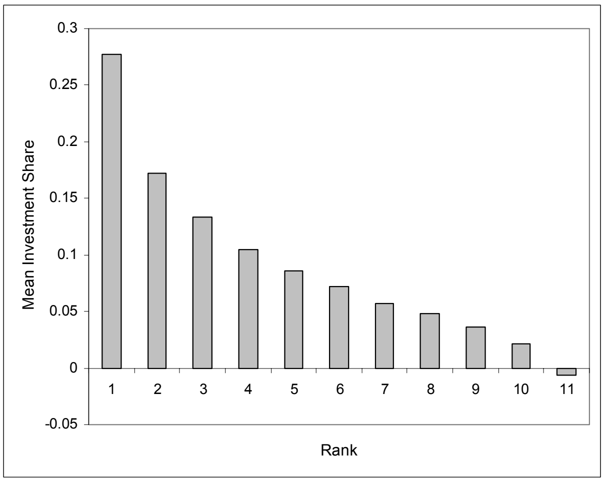

Figure 8: Mean investment shares by capital growth rate rank.

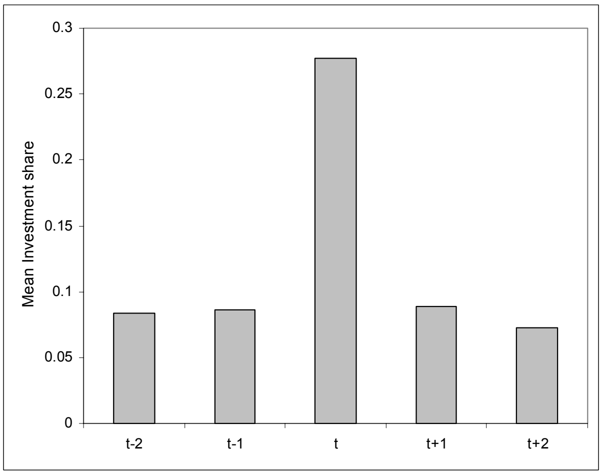

Figure 9: Mean pre- and post-spike investment growth rates.

As can be seen in figure 8, about 60 percent of the total investment volume during the period is, on average, carried out in only three years. Moreover, when looking at the timing of the investments as shown in figure 9, we see that the same pattern emerges as when studying growth rates. This is interesting, since we can then be more confident that the patterns described throughout this paper are not an artifact of our assumption of the evolution of the capital stock over time.

D Unbalanced Panel

To investigate whether our selection of only ongoing firms is driving our results, we have also experimented with an unbalanced panel. To obtain such a panel, we follow the cleaning procedure as described in Appendix A, but we only require the firms to be observed in seven consecutive years, which gives us a sample of 2321 firms. The reason for only using firms observed seven years or more in a sequence is that we need to calculate capital stocks, and since we drop the first four observations to mitigate the initial value problem, we are left with at least three observations for each firm. Then, since lagged values of capital are used, we effectively have two observations for each firm - which is the minimum number of observations needed to estimate the firm-specific constant for each firm.

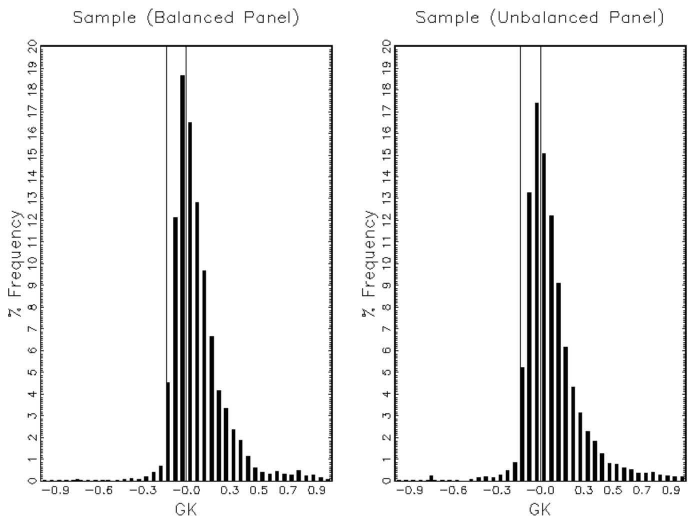

Figure 10: Density of the growth rates of capital for the unbalanced sample.

As can be seen in figure 10, the distribution of the growth rates for the unbalanced panel is very similar to the distribution of the balanced panel. Thus, figure 10 does not give any evidence to the hypothesis that the results are biased in favor of finding irreversibility due to our sample selection.

In figure 11, the adjustment function for the unbalanced sample is presented. This function is similar to the one obtained from the balanced sample, the only difference is that the value of the top intervals is somewhat higher for the unbalanced panel. However, this difference do not give rise to any qualitatively different results for the aggregate responsiveness to aggregate shocks, as can be seen in figure 12. The aggregate responsiveness is estimated in the same way as for the balanced panel; in this case, the reponsiveness is also affected by changes in the population over time, however. Overall, the results from the unbalanced panel do not indicate sample selection to be a crucial issue here.

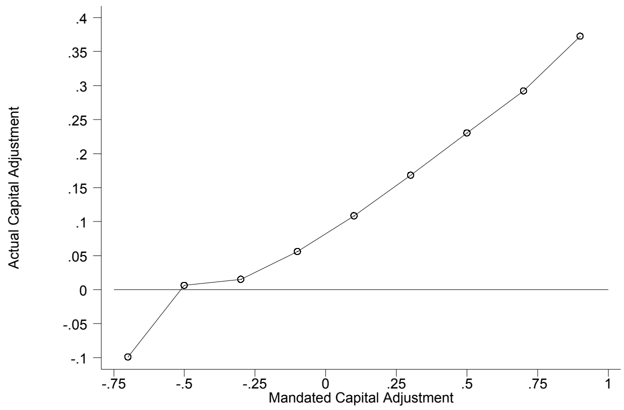

Figure 11: Empirical adjustment function, i.e. the averages of actual adjustment, $GK_{i,t}$, over nine intervals defined on $m^p \in [-0.8, 1]$ for the unbalanced panel.

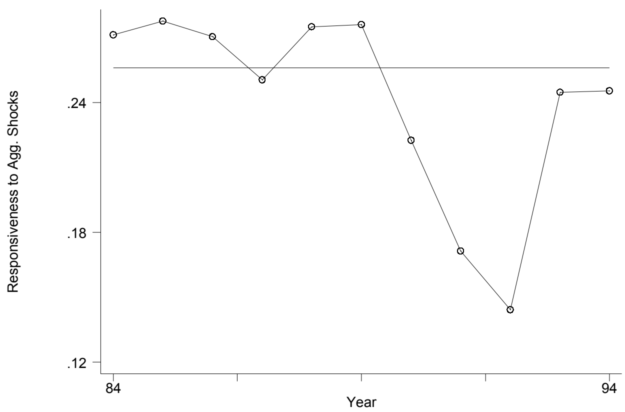

Figure 12: Responsiveness of aggregate capital growth to aggregate shocks ($\partial GK_{A,t}/\partial m_t^p$) for the unbalanced panel.

E Measurement Errors

In this appendix, we make an attempt at evaluating the effects of classical measurement errors in our measure of mandated capital adjustment. For clarity, we restate equation (22):

$$m_{i,t} = \eta_i \left[y_{i,t} - k_{i,t-1} - c_{i,t} + v_i \right]. \tag{22}$$

Since the variables on the right-hand side of (22) might be measured with error, it obviously follows that $m_{i,t}$ may also be measured with an error. Here, we try to control for this error by using the first lag of $m_{i,t}$ as an instrument for $m_{i,t}$. Given that we only try to control for classical measurement errors, lags should be a valid instrument. However, a caveat should be mentioned at this point. The relevance of the instrument we use hinges on the true underlying adjustment process. If the firms reduce the deviation between the desired and the actual stock of capital with a fraction in each period, due to a symmetric convex adjustment cost, this instrument should be highly relevant. However, at the other extreme, if firms adjust completely in each period, the instrument will have no relevance whatsoever. Between these extremes, we might also have an asymmetric relevance. For example, if an irreversibility constraint drives the adjustment behavior, the relevance of lagged mandated capital adjustments as an instrument for current mandated capital adjustments depends on whether $m_{i,t-1}$ is strongly negative or not. With these considerations in mind, we continue by estimating the adjustment function, applying the non-parametric estimator described in the main text by replacing $m_{i,t}$ with the prediction of $m_{i,t}$, estimated using the following specification

$$m_{i,t} = a_{0,i} + a_{1,i} m_{i,t-1} + e_{i,t}, \tag{30}$$

where a_0 and a_1 are firm-specific parameters estimated for each firm in the balanced panel. Note that we lose one observation for each firm, relative to the sample used in the main text.

In figure 13 (dashed line), the resulting adjustment function is depicted for the relevant intervals, i.e. intervals containing at least 30 observations. In figure 13, we have also plotted the adjustment function without correcting for the measurement error we obtain using the same sample as when correcting for the measurement error. When comparing the adjustment

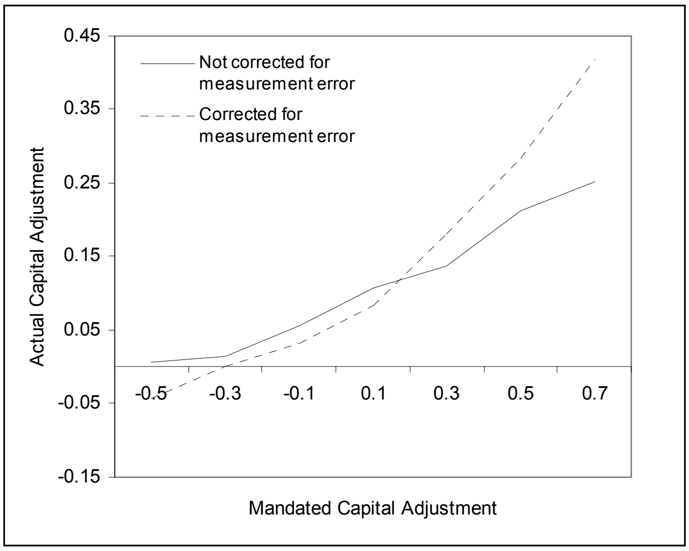

Figure 13: Empirical adjustment function corrected (dashed line) and not corrected (solid line) for measurement error in $m^p_{i,t}$.

functions, we see that the slope increases when we correct for measurement errors. This is expected, since classical measurement errors tend to attenuate slope parameters. It can also be seen that the asymmetry in the adjustment behavior between positive and negative mandated capital adjustment is more pronounced when correcting for measurement errors.

Finally, we check if the behavior of the responsiveness of aggregate capital growth to aggregate shocks is affected by measurement errors. This is done by using the same approach as described in the main text. Since we only have limited information about the adjustment function for values of mandated capital adjustments outside the interval -0.6 to 0.8 (when controlling for measurement errors), we restrict our attention to firms with an $m^p_{i,t} \in [-0.6, 0.8]$ in all periods. This leaves us with a sample of 192 firms.

In figure 14, the responsiveness for aggregate capital growth to aggregate shocks when controlling for measurement errors is depicted by year. In figure 15, we have plotted the analogous results when not correcting for measurement errors. As in the main text, the straight lines in figures 14 and 15 depict the responsiveness of aggregate capital growth to aggregate shocks, if the adjustment function were linear. Although the level of the estimated

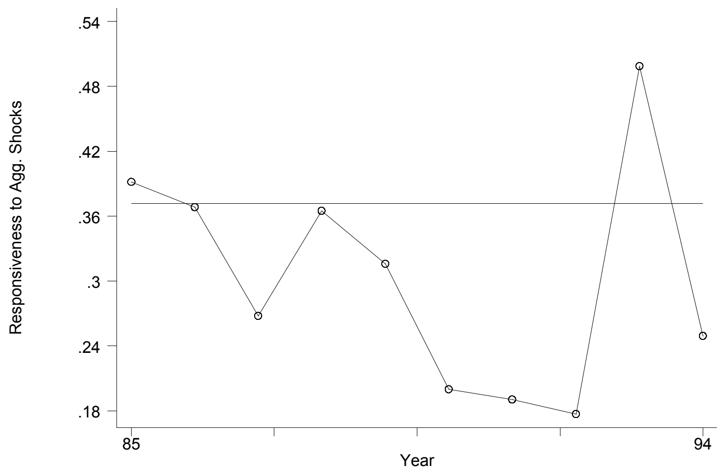

Figure 14: Responsiveness of aggregate capital growth to aggregate shocks per year when correcting for measurement errors in $m^p_{i,t}$.

responsiveness is shifted upwards when controlling for measurement errors, the behavior of the responsiveness over time is similar to what we find when not controlling for measurement errors.

Overall, controlling for measurement errors does not seem to qualitatively change our conclusions. However, the above caveats should be kept in mind.

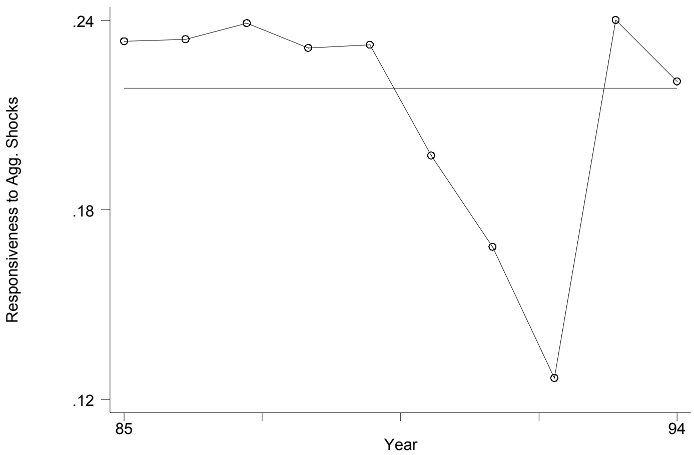

Figure 15: Responsiveness of aggregate capital growth to aggregate shocks per year not correcting for measurement errors in $m^p_{i,t}$.

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