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Capital Heterogeneity: Does it Matter? Fundamental Q and Investment on a Panel of Italian Firms

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SUMMARY

In this paper we study the determinants of investment decisions at the firm level with heterogeneous capital goods. We exploit a newly developed panel dataset of small and medium-sized firms which allows us to distinguish between purchases, sales, and net acquisitions of capital goods. We distinguish between equipment and structures and test the assumption of convex adjustment costs. Since our firms are mostly unlisted, the standard Q model based on stock market valuation is no longer appropriate. Instead, we use the fundamental Q approach proposed by Abel and Blanchard (1986) and Gilchrist and Himmelberg (1995) and extend it to the case of several capital inputs. The results show that the standard convex costs model fits very well equipment and but not structures. We find evidence for non-convexities in the case of structures.

Keywords: Investment, Q, heterogeneous capital goods, VAR estimation, panel data

JEL: D24, G31, C33, C34

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1 Introduction

Firms own and use many types of capital goods in the production process. A typical distinction is between equipment and structures - between the machines and instruments used in producing goods and the buildings where the production process takes place. These various capital goods command different prices, are characterized by different depreciation patterns, and receive different tax treatment. The possibility of combining diverse capital inputs into a single aggregate relies on very restrictive assumptions on the firm's technology, specifically the various capital goods must be perfect substitute for one another. This implies that the firm can produce more output by applying more machines or, indifferently, more buildings.

The perfect substitutability among varieties of capital is typically rejected by the data in static production analyses (Berndt and Christensen, 1973; Denny and May, 1978). In addition, dynamic investigations produce different magnitudes for the costs of adjusting different capital inputs (Pindyck and Rotemberg, 1983; Peeters, 1998). Yet the most recent developments in the investment literature, which look at the role of non-convexities and irreversibility, still assume that different types of capital goods can be combined into a single aggregate (see, for instance, Abel and Eberly, 1999).

The bulk of applied investment literature is based on the assumption of capital homogeneity. Structural models of investment behavior fall into two groups: Tobin's Q model and Euler equation model. Each formulation suffers from difficulties when confronted with the data. In the Euler model the restrictions implied by the theory are often rejected (Whited, 1996); Q models often produce estimated coefficients for the Q variable, ranging between 0.003 and 0.05 (Whited, 1994), which imply unrealistically high marginal adjustment costs and therefore implausibly slow adjustment speeds. One difficulty with these models is the assumption of capital homogeneity. This does not allow consideration of other factors that affect investment composition such as tax policy, price changes, demand and supply shocks. Recent studies on non-convexities in adjustment costs and irreversibilities suggest that aggregation of capital inputs may crucially hide those patterns (Eberly, 1997; Abel and Eberly, 1999).

In this paper we relax the single capital good assumption. The literature on investment with many capital inputs is scant. Wildasin (1984) shows that the various capital investments cannot be related to the single Tobin's Q variable in a unique way. In that analysis Q turns out to be equal to a weighted average of the different capital stocks, the weights being given by the shadow values of individual capital inputs. Hayashi and Inoue (1991) relate (uniquely) the growth rate of a scalar index of several capital inputs to Tobin's Q. They then test the model on Japanese panel data. However, the theoretical model rests on a maintained weak separability hypothesis for the capital inputs within the firm's profit function. Chirinko (1993) uses and applies on U.S. aggregate data the result of Wildasin (1984) and estimates an equation in which the specific capital investment relative to the aggregate stock depends on Tobin's Q and on the ratios of the other capital investments to the aggregate stock. When capital is homogenous the coefficients of these investment regressors are equal, an hypothesis the author rejects when distinguishing between equipment and structures. Cummins and Dey (2000) choose instead an Euler equations approach to study investment in equipment and structures on U.S. firm level data. They postulate a translog technology and quadratic adjustment costs. When interrelations among these costs are permitted, estimated own marginal adjustment costs are positive, significant, and reasonably sized, the cross effects are negative and significant, while the whole adjustment costs function turns out to be convex in its arguments. Finally, Bond and Cummins (2000) study US firm investment behavior with regard to tangible and intangible capital. The authors develop and estimate a single equation model where the tangible investment-capital ratio depends linearly upon Tobin's Q and on the ratio between intangible investment and tangible stock. A similar equation was proposed by Galeotti and Schiantarelli (1991) in the case of capital and labor as quasi-fixed factors; however, due to the unobservability of the stock of intangibles, Bond and Cummins (2000) end up taking the ratio between the two stocks to be time invariant.[1]

This paper studies investment in heterogeneous capital goods with a focus on adjustment costs. It exploits a newly developed panel dataset on Italian

[1] In the area of the investment literature that deals with capital markets imperfections a small number of contributions analyze the impact that financing constraints have on both fixed and R&D investment simultaneously. However, when heterogeneity of capital inputs is allowed for, traditional Q equations are no longer employed and several papers resort to unrestricted partial adjustment or error correction specifications as an alternative to Euler equations. Examples of these papers are Harhoff (1998) and Bond, Harhoff, and Van Reenen (1999). The relationship between fixed and R&D capital is also investigated also by Mairesse and Siou (1984), Lach and Schankerman (1989), and Nickell and Nicolitsas (1996).

firms, described in detail below, which allows a disaggregation between main types of capital assets and includes separate information on purchases and sales of these capital goods. In keeping with the bulk of the literature we consider here the distinction between equipment and structures, while leaving the extension to one or more types of intangible capital (R&D, advertising, and the like) to future research. We start by reconsidering the issue of adjustment costs concentrating on the "usual" convex costs case and quantifying the difference in such costs associated with different capital types.

In order to capture the role of investment opportunities we rely on the notion of fundamental Q. Previous studies on standard Q models using Italian firm-level data (Galeotti, Schiantarelli, and Jaramillo, 1994) only considered listed companies, neglecting a very high number of production units. While in principle the standard Q model is not limited to the case of a single quasi-fixed factor, in practice most company accounts do not include usable information on investment in individual capital assets. Franzosi (1999) estimates a model of investment and fundamental Q using Italian data in the single capital good case. We extend the fundamental Q approach to heterogenous capital inputs and use a large panel of firm-level data which record mostly small and medium firms not listed in the stock market.

The fundamental Q approach was first proposed by Abel and Blanchard (1983) who estimated investment behavior on aggregate U.S. manufacturing data. The extension to panel data was implemented by Gilchrist and Himmelberg (1995), followed by similar applications by Franzosi (1999) and Alesina, Ardagna, Perotti, and Schiantarelli (1999). Unlike the traditional Q model, in the fundamental Q approach there is no need of a strong market efficiency hypothesis concerning the stock market. Moreover, the fundamental Q model allows us to analyze the important issues of financing constraints and excess sensitivity of investment to cash flow, as shown by Gilchrist and Himmelberg (1998). However, all these papers rely crucially on the capital homogeneity assumption that we relax in this paper.

The paper is organized as follows. In Section 2 we present a theoretical model of heterogenous investment based on the fundamental Q approach. In Section 3 we draw from Gilchrist and Himmelberg (1995, 1998) and obtain proxies for the present value of future marginal profits generated by different capital inputs: in other words we compute fundamental Q's for each capital good. These are obtained by evaluating a linear expectation of the present discounted stream of marginal profits from a set of VAR forecasting equations. In Section 4 the dataset is described and Section 5 discusses the estimation methodology and presents the empirical results. Conclusions and further research steps are contained in the last section.

2 The Investment Model with Two Capital Inputs

Our model follows the fundamental Q approach proposed by Abel and Blanchard (1986) for aggregate investment and for panel data by Gilchrist and Himmelberg (1995). Investment in individual capital goods is the outcome of firms' intertemporal optimization in which the profit opportunities of investing in a certain capital good are compared at the margin with its cost. These opportunities are represented by the shadow price of capital or fundamental Q, which is evaluated by an auxiliary model which described in the next section. Investment is assumed to be reversible and there are convex costs of adjusting the capital stock. The model is developed for two types of capital goods. We specify these as equipment and structures.

Consider a firm which, at the start of period t, decides the amount to invest in each type of capital goods, I_1 and I_2, in order to maximize the expected present value of the future stream of profits:

$$V\left(K_{1,t}, K_{2,t},\theta_t, \xi_{1,t}, \xi_{2,t}\right) = \max_{\{I_{1,t},I_{2,t}\}_{t=0}^{\infty}} E\left\{\sum_{t=0}^{\infty}\beta^t \left[\Pi\left(K_{1,t}, K_{2,t}, \theta_t\right) - \left[c^1\left(I_{1,t}, K_{1,t}, \xi_{1,t}\right) + c^2\left(I_{2,t}, K_{2,t}, \xi_{2,t}\right)\right] - \left(p_{1,t}I_{1,t} + p_{2,t}I_{2,t}\right) \mid \Omega_t\right]\right\} \tag{1}$$

subject to the following laws of motion:

$$K_{1,t+1} = K_{1,t}\left(1-\delta_1\right) + I_{1,t} \tag{2}$$

and:

$$K_{2,t+1} = K_{2,t}\left(1-\delta_2\right) + I_{2,t} \tag{3}$$

where $V(.)$ is the firm's value function, K_1 the stock of equipment, K_2 the stock of structures, θ is a shock to profits, β the real discount rate, $\Pi\,(.)$ indicates current profit, $c^1(.)$ and $c^2(.)$ represent the adjustment cost functions,

$I_1$and I_2 are gross investments with corresponding acquisition prices p_1 and p_2, $\xi_1$and ξ_2 are shocks to individual adjustment costs, δ_1 and δ_2 are the rates of physical depreciation. E is the expectations operator conditional on information available at t, Ω_t. The two laws of motion assume that there is a one-period gestation lag before additions to the capital stocks become fully productive.

The discount rate β is calculated as the sample average of the following expression:

$$[1 + (1 - \tau_t)\, r_{i,t} - z_t]^{-1} \tag{4}$$

where $r_{i,t}$ is the nominal rate of interest, computed by dividing interest payments on financial debt (bank loans, factoriing and leasing) by the corresponding stock of debt, z_t is the inflation rate, and τ is the tax rate on firm profits (see the appendix for variable definitions).[2] The price of each capital good is normalized by the output price. We assume that variable inputs are optimized out: in order to simplify the notation we omit the explicit dependence of the profit function on variable input prices.

By solving equations 1-3 we obtain the following first order conditions:

$$p_{1,t} + \frac{\partial c^1\left(I_{1,t}, K_{1,t}, \xi_{1,t}\right)}{\partial I_{1,t}} = E\left[q_{1,t} \mid \Omega_t\right] \tag{5}$$

and:

$$p_{2,t} + \frac{\partial c^2\left(I_{2,t}, K_{2,t}, \xi_{2,t}\right)}{\partial I_{2,t}} = E\left[q_{2,t} \mid \Omega_t\right] \tag{6}$$

where $E\left[q_{1,t} \mid \Omega_t\right]$ and $E\left[q_{2,t} \mid \Omega_t\right]$ are the shadow values of equipment and structures respectively in period t. In particular:

$$q_{1,t} = \sum_{s=1}^{\infty} \beta^s \left(1 - \delta_1\right)^{s-1} \left[\left(\frac{\partial \Pi\left(K_{1,t+s}, K_{2,t+s}, \theta_{t+s}\right)}{\partial K_{1,t+s}}\right) - \left(\frac{\partial c^1\left(I_{1,t+s}, K_{1,t+s}, \xi_{1,t+s}\right)}{\partial K_{1,t+s}}\right)\right] \tag{7}$$

[2] We follow Abel and Blanchard (1986) and Gilchrist and Himmelberg (1995) who consider the average over time and considering any firm-specific effect as captured by the fixed effect.

and

$$q_{2,t}=\sum_{s=1}^{\infty}\beta^{s}\left(1-\delta_{2}\right)^{s-1}\left[\left(\frac{\partial\Pi\left(K_{1,t+s},K_{2,t+s},\theta_{t+s}\right)}{\partial K_{2,t+s}}\right)-\left(\frac{\partial c^{2}\left(I_{2,t+s},K_{2,t+s},\xi_{2,t+s}\right)}{\partial K_{2,t+s}}\right)\right] \tag{8}$$

where $q_{1,t}$ and $q_{2,t}$ are equal to the discounted stream of future (net) marginal profitability of these two types of capital. These are referred to as fundamental Q's. According to equations 5 and 6 the optimal path of each type of capital good requires that the marginal cost of an additional unit of capital, given by acquisition plus installation costs, be equal to the expected marginal benefit, or fundamental Q.

In order to make this theory operational we need to parametrize the adjustment costs functions and solve the problem of the unobservability of the fundamental Q. Following the bulk of the literature on investment decisions, we consider quadratic linear homogeneous functional forms relating to each type of capital:

$$c^{1}(I_{1,t},K_{1,t},\xi_{1,t})=\frac{\alpha_{1}}{2}\left(\frac{I_{1,it}}{K_{1,it}}-\gamma_{1,i}-\xi_{1,it}\right)^{2}K_{1,it} \tag{9}$$

and:

$$c^{2}(I_{2,t},K_{2,t},\xi_{2,t})=\frac{\alpha_{2}}{2}\left(\frac{I_{2,it}}{K_{2,it}}-\gamma_{2,i}-\xi_{2,it}\right)^{2}K_{2,it} \tag{10}$$

where we have now added the firm subscript i. These adjustment cost functions imply that the marginal cost of changing each capital input is linear in the own investment-capital ratio. Each adjustment cost function also depends on an idiosyncratic technology shock, $\xi_{1,it}$and $\xi_{2,it}$, which is assumed to be observed by the firm but unknown to the econometrician. We also assume that the $\xi's$ are uncorrelated across time. The parameters $\gamma_{1,i}$ and $\gamma_{2,i}$ are firm-specific parameters which capture unobserved heterogeneity across firms. The adjustment cost parameters $\alpha_1$and α_2 measure the costliness of investment and relate to the speed of adjustment of current capital towards its desired steady state value.

Substituting 9 into 7 and 10 into 8 we obtain the following expression for investment in equipment and structures respectively:

$$\frac{I_{1,it}}{K_{1,it}} = \gamma_{1,i} + \frac{1}{\alpha_1} E\left[q_{1,it} \mid \Omega_{it}\right] + \xi_{1,it} \tag{11}$$

and:

$$\frac{I_{2,it}}{K_{2,it}} = \gamma_{2,i} + \frac{1}{\alpha_2} E\left[q_{2,it} \mid \Omega_{it}\right] + \xi_{2,it} \tag{12}$$

Equations 11 and 12 express investment as a function of the own fundamental Q. Note that the acquisition price of investment does not appear explicitly because we do not have firm-specific observations on prices. We will use time dummies as part of the $\gamma_i' s$ to capture these and other time varying effects which are firm-invariant. Now let $\beta^s (1 - \delta_1)^{s-1} \equiv (\lambda_1)^s$and $\beta^s (1 - \delta_2)^{s-1} \equiv (\lambda_2)^s$in equations 7 and 8 and rewrite them as:

$$E\left[q_{1,it} \mid \Omega_{it}\right] = \sum_{s=1}^{\infty} \lambda_1^s \left[\pi_{1,it+s} \mid \Omega_{it}\right] \tag{13}$$

and:

$$E\left[q_{2,it} \mid \Omega_{it}\right] = \sum_{s=1}^{\infty} \lambda_2^s \left[\pi_{2,it+s} \mid \Omega_{it}\right] \tag{14}$$

where $\pi(.)$ indicates the marginal profit associated with each capital type. [3] In order to develop our model, we need a measure for the shadow prices of capital $E\left[q_{1,it} \mid \Omega_{it}\right]$ and $E\left[q_{2,it} \mid \Omega_{it}\right]$.

[3] Note that, following Abel and Blanchard (1986) and Gilchrist and Himmelberg (1995), we consider the marginal effects on adjustment costs of changes in capital stocks in 7 and 8 as negligible in each period.

3 Fundamental Q for Heterogeneous Capital Goods

Following Abel and Blanchard (1986) and Gilchrist and Himmelberg (1995), the shadow value of capital is computed by constructing the present value terms through the estimation of a set of VAR (vector autoregression) equations for the vector of the state variables which forecast the marginal profitability of capital. We extend their methodology to heterogenous capital. The important feature of the approach is that it does not require knowledge of the stock market valuation of the firm and is therefore feasible for unlisted companies as in our case.

To construct the expectations of the future marginal profitability of capital we assume that the firm's technology is Cobb-Douglas. Under perfect competition in the output market, we may relate marginal profits of capital to the observed variables as follows:

$$\frac{\partial \Pi_{it}}{\partial K_{j,it}} = \rho_{j,i} \left(\frac{\Pi_{it}}{K_{j,it}} \right) \tag{15}$$

where $j = 1, 2$, and $\rho_{j,i}$ is the output elasticity of capital. In equation 15, the marginal profit relating to each capital input is proportional to the corresponding profit rate. Profits in this paper are proxied by operating income. If, alternatively, we assume imperfect competition, then we have:

$$\frac{\partial \Pi_{it}}{\partial K_{j,it}} = \sigma_{j,i} \left(\frac{S_{it}}{K_{j,it}} \right) \tag{16}$$

where $j = 1, 2$, S indicates sales and $\sigma_{j,i} = \left(1 + \eta_i^{-1}\right) \rho_{j,i}$ with η_i representing the firm level price elasticity of demand. In this case the marginal profit relating to each capital input is proportional to the sales to capital ratio.

Consider a vector x_{it} comprised of capital-specific operating income to capital and sales to capital ratios and any other variables containing information which is useful for forecasting the future marginal profitability of capital. More precisely, the vector x_{it} contains the r.h.s. of 15 and 16, henceforth denoted by oi_{it} and s_{it} respectively. Assume that x_{it} follows the stationary first order autoregressive stochastic process:

$$x_{it} = Ax_{it-1} + f_i + d_t + u_{it} \tag{17}$$

where A is the $VAR(m)$ companion matrix, x_{it-1}represent lagged values of x_{it}, f_i is a vector of firm unobserved effects, d_t is a vector of shocks common to all firms and u_{it} is a vector of disturbance terms, orthogonal to x_{it-1}. To keep notation simple, in what follows we do not distinguish between different capital goods, although our objective is to compute three fundamental Q's, one for the aggregate capital stock, one for equipment and one for structures.

Assume that variables dated t are part of the information set, i.e. $x_{it} \in \Omega_t$. Since we are assuming a stationary process, the expectation of x_{it+s} given x_{it} may be written as:

$$E\left[x_{it+s} \mid x_{it}\right] = A^s x_{it} \tag{18}$$

where we have omitted the terms f_i and d_t. Under the assumption of a one-period gestation lag, the shadow value of capital or fundamental Q may be expressed as:

$$\begin{aligned} E\left[q_{it} \mid \Omega_{it}\right] &= \sum_{s=1}^{\infty} \lambda^s E\left[\pi_{it+s} \mid \Omega_{it}\right] \\ &= \sum_{s=1}^{\infty} \lambda^s E\left[c' x_{it+s} \mid x_{it}\right] \\ &= \sum_{s=1}^{\infty} c' \lambda^s A^s x_{it} \\ &= c' \left(I - \lambda A\right)^{-1} \lambda A x_{it} \\ &= FQ_{it} \end{aligned} \tag{19}$$

where c is a vector with the first element equal to one and zeros elsewhere.[4] Setting $m = 2$, in matrix notation 19 implies the following expression for the case of perfect competition: [5]

[4] If we assume that variables dated t are not part of the information set, the formula of fundamental Q in 19 is slightly different. If we compute fundamental Q in this way, the empirical results of the regressions reported in the next sections are somewhat inferior but the main conclusions hold true.

[5] In the case of imperfect competition we have to adjust the row vectors in order to obtain forecasts of the sales variable.

$$\begin{bmatrix} 1 & 0 & 0 & 0 \end{bmatrix} \left[\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} - \lambda \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ 1 & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & a_{34} \\ 0 & 0 & 1 & 0 \end{bmatrix} \right]^{-1} \begin{bmatrix} oi_{it-1} \\ oi_{it-2} \\ s_{it-1} \\ s_{it-2} \end{bmatrix} \tag{20}$$

where $a_{11}, a_{12}, a_{13}, a_{14}, a_{31}, a_{32}, a_{33}, a_{34}$ are the coefficients of the lagged values of operating income and sales, both scaled by capital stock in the VAR(2) equations.[6] Since in our VAR equations we regress operating income and sales only on their lagged values (see Campbell and Shiller, 1987), the first and the third elements in the second and fourth row respectively are equal to one (zero elsewhere). The term λ varies according to the type of capital: $\lambda = 0.8614$ for total investment, $\lambda = 0.8394$ for equipment and $\lambda = 0.8944$ in the case of structures.[7] As said, expressions 19 and 20 are based on the assumption of one-period gestation lag.[8] Putting everything together, and letting j index aggregate capital, equipment and structures, investment as a function of fundamental Q is (a hat refers to parameters which have been estimated in a previous stage):

$$\frac{I_{j,it}}{K_{j,it}} = \frac{1}{\alpha_j} c' \left(I - \lambda_j \widehat{A}_j \right)^{-1} \lambda_j \widehat{A_j} x_{j,it} + f_{j,i} + \nu_{j,t} + \xi_{it} \tag{21}$$

$$= \frac{1}{\alpha_j} FQ_j + f_{j,i} + \nu_{j,t} + \xi_{it} \tag{22}$$

[6] oi_{it} is adjusted by the the output elasticity of capital and s_{it} also by the price elasticity of demand as explained in Section 5.

[7] These values correspond to the sample average of time and firm specific λs, i.e.:

$$\tilde{\lambda}_j = \frac{1}{NT} \sum_{h \in I} \sum_{t \in T} \beta_{ht} (1 - \delta_{j,ht})$$

where j indicates equipment, structures, or total capital, h specifies an industry; $\delta_{j,ht}$ is the rate of physical depreciation which varies by industry (indexed by I, there are N industries).

[8] We have also experimented the case of absence of gestation lags, which implies that today's investment becomes immediately productive. There were only qualitative differences but the one period gestation lag appeared to deliver more robust results.

4 Data Description

We use data from Italy's Company Accounts Data Service (CADS), a large database with information on the balance sheets and income statements of more than 52,000 Italian firms covering all industries from 1982 to 1995. In addition to company accounts the database contains information on firm's demographics, location, sector, type of organization, ownership status, the composition of the board of management and the board of auditors. CADS is well representative of the population of Italian companies, covering over 50% of the value added produced by the firms included in the Census of the Italian Central Statistical Office. The dataset we use comprises 5086 manufacturing firms, which, after applying cleaning criteria, becomes a panel of 1539 companies for the period 1982-1995. Trimming rules, variable definition and construction are discussed in the appendix.

We define net investment as purchases minus sales of fixed capital, and gross investment, as purchases only. Unlike gross investment, net investment may take negative values, as shown in the first panel in Table 1, when capital sales are larger than purchases. Aggregate net investment shows a lower incidence of zeros and of negative investment and indicates that aggregation tends to smooth out the discontinuities which are likely to characterize structures. Indeed, the latter shows the highest incidence of zero net investment, 13.8 percent against 0.52 percent in the case of equipment and 0.43 percent in the case of total net investment. This indicates the possibility of fixed components in the structure of adjustment costs and discontinuous behavior in the case of investment in structures which affect the relationship between investment and fundamental Q. In the case of equipment, zero net investment episodes are markedly less frequent than positive and negative investment cases. [9] Net investment is the result of buying and selling and zero investment may hide simultaneous buying and selling of capital goods. This is confirmed by our data which show that companies buy and sell capital simultaneously, even if sales show a lower frequency being more time-concentrated and to a lesser amount than purchases. Moreover, even if disinvestment, at both net and gross level, does not occur very often, in our data about 72%, 69% and 57% of firms sell total capital, equipment and

[9] Tables A.3.1-A.3.3 in the appendix present respectively the distribution of firms by sector and size, the frequency of zero and of negative net investment by sectors and size respectively. Inaction is relatively more frequent in small companies, while net sales of structures are more frequent in large firms.

structures respectively, in at least one year in the sample. It is therefore important to look at purchases and sales of each capital good separately. In the second panel of Table 1 we also report the temporal concentration of purchases and sales for aggregate capital, equipment and structures.

Table 1 Net and Gross Investment

	Aggr.	**Equip.**	**Struct.**
Frequency:			
Positive net investment	97.20	90.15	74.43
- purchases only	27.63	30.32	28.88
- purchase > sales	69.57	59.83	45.55
Zero net investment	0.43	0.52	13.80
- no purchases and no sales	0.39	0.48	13.78
- purchases = sales	0.04	0.04	0.02
Negative net investment	2.37	9.33	11.77
- sales only	0.30	2.31	3.02
- sales > purchases	2.08	7.02	8.75
Temporal concentration of purchases:			
- frequency of firms with zero purchase	0.69	2.79	16.80
- ratio of maximum annual purchase to total purchases over the sample period	26.54	29.00	48.37
Temporal concentration of sales:			
- frequency of firms with zero sales	28.02	30.80	42.66
- ratio of maximum annual sale to total sales over the sample period	60.63	65.13	73.88
Number of firms	1539		
Number of observations	16929		

When we look at pure purchases of capital goods we find that the frequency of firms with zero purchases is much higher for structures than for equipment and total capital. As in the case of net investment, when we aggregate over different types of goods we tend to hide the intermittent nature of structures. The data show that sales are more episodic than purchases. Moreover, pure zero sales are very frequent for all the types of goods. In the second panel of Table I, we report a measure of temporal concentration for both purchases and sales. [10] In our sample the ratio of maximum annual purchase (sale) to total purchases (sales) over the sample period suggests that investment in structures is characterized by a higher degree of concentration than in the case of equipment: 48.37% against 29% in the case of pure purchases and 73.9% against 65.13% in the case of pure sales. The latter comparison shows how disinvestment is in general much more concentrated than investment. These findings are confirmed if we look at the distribution of net investment, purchases and sales in the next tables.

Table 2 presents the summary statistics for the variables we use: net investment (i_T, i_E, i_S), gross investment or purchases (i_T^+, i_E^+, i_S^+) and disinvestment or sales (i_T^-, i_E^-, i_S^-), real sales (s_T, s_E, s_S), and operating income (oi_T, oi_E, oi_S). All these variables are divided by the stock of total capital (T), equipment (E), and strcutres (S). The positive skewness suggests that investment is temporally concentrated; in particular, this is true for structures which exhibit a zero net investment rate in the first quartile. Purchases follow a similar pattern. Most of the disinvestment is small and have a markedly skewed distribution, with the highest degree in the case of structures. The mean annual rates of disinvestment are as low as 0.037, 0.040 and 0.035 respectively, strongly affected by the high number of zero episodes. Given the high frequency of positive outliers due to the skewness of our data, we use pseudo-standard deviation which is a more robust as a measure of variability.[11]

[10] See Doms and Dunne (1994).

[11] The pseudo-standard deviation is defined as the ratio of the interquartile range (Q3-Q1) and 1.349 where 1.349=2*0.674 is the interval containing 50% of the cases in a normal distribution.

Table 2 Descriptive Statistics

	Q_1	$Median$	Q_3	$Mean$	$Pseudo - s.dev.$	$Skewness$
i_T	0.066	0.129	0.228	0.178	0.120	3.632
i_E	0.065	0.157	0.289	0.221	0.166	4.199
i_S	0	0.037	0.181	0.177	0.134	4.258
i_T^+	0.083	0.155	0.274	0.215	0.141	7.724
i_E^+	0.076	0.168	0.304	0.261	0.169	6.723
i_S^+	0.003	0.044	0.194	0.212	0.142	7.727
i_T^-	0	0.002	0.014	0.037	0.010	22.601
i_E^-	0	0.002	0.011	0.040	0.008	21.202
i_S^-	0	0.0001	0.004	0.035	0.003	32.118
s_T	2.282	3.432	5.347	4.344	2.272	2.770
s_E	3.472	5.565	9.451	7.910	4.432	4.223
s_S	5.939	9.651	16.017	13.278	7.471	3.305
oi_T	0.235	0.365	0.563	0.459	0.243	3.863
oi_E	0.365	0.588	0.968	0.832	0.448	6.767
oi_S	0.591	1.015	1.741	1.449	0.852	5.156

In Tables 3 and 4 we report the Markovian transition probabilities for aggregate capital, equipment and structures distinguishing between purchases and sales, over the sample period. In the tables we consider two regimes: positive investment and zero investment (for instance in Table 3: $\mathrm{I}_{t+1}^{+} > 0$ and $\mathrm{I}_{t+1}^{+} = 0$ respectively). The transition matrices should be read as follows: the first cell in the first panel of Table 3 indicates that 8 firms did not purchase any capital in period t and continued not to purchase in period t+1. In the second line, in bold, we report the frequency, i.e. the probability of changing or remaining in the same state between one year and another. Both tables confirm that investment in structure is more episodic although it is not unusual. In general, sales are characterized by a higher number of transitions between the two different states, indicating that these may be consistent with a discrete decision process.

Table 3 Transition Matrix for Zero and Positive Investment: Purchases

	Aggregate	
	$I_{t+1}^{+} = 0$	$I_{t+1}^{+} > 0$
$I_t^{+} = 0$	8	96
	7.69	**92.31**
$I_t^{+} > 0$	104	15181
	0.68	**99.32**
	Equipment	
	$I_{t+1}^{+} = 0$	$I_{t+1}^{+} > 0$
$I_t^{+} = 0$	39	382
	9.26	**90.74**
$I_t^{+} > 0$	401	14568
	2.68	**97.32**
	Structures	
	$I_{t+1}^{+} = 0$	$I_{t+1}^{+} > 0$
$I_t^{+} = 0$	1025	1614
	38.84	**61.16**
$I_t^{+} > 0$	1475	11276
	11.57	**88.43**
Total no. of obs.	15390	No. of firms: 1539

Table 4 Transition Matrix for Zero and Positive Investment: Sales

	Aggregate	
	$I^-_{t+1} = 0$	$I^-_{t+1} > 0$
$I^-_t = 0$	2289	2334
	49.51	**50.49**
$I^-_t > 0$	1357	9410
	12.60	**87.40**
	Equipment	
	$I^-_{t+1} = 0$	$I^-_{t+1} > 0$
$I^-_t = 0$	2642	2377
	52.64	**47.36**
$I^-_t > 0$	1415	8956
	13.64	**86.36**
	Structures	
	$I^-_{t+1} = 0$	$I^-_{t+1} > 0$
$I^-_t = 0$	3760	3038
	55.31	**44.69**
$I^-_t > 0$	2283	6309
	26.57	**73.43**
Total no. of obs.	15390	No. of firms: 1539

5 Estimation and Empirical Results

We estimate our investment model using a two-stage procedure. In the first stage we estimate a VAR model for each type of capital good and calculate the corresponding fundamental Q. In the second stage we estimate the individual investment equations as functions of the fundamental Q's obtained from the first stage.

In the first stage we follow Holtz-Eakin, Newey and Rosen (1988) who extend the VAR methodology to longitudinal data. We adopt a VAR(2) specification and estimate the coefficient matrix A in equation 17. Using the same notation in equation 17, the set of regressors, x_{it-1} is comprised of operating income and sales divided by capital stocks and adjusted by ρ_j and σ_j, the technology and demand paramters which appear in expressions 15 and 16. Following Gilchrist and Himmelberg (1998) these terms are calculated as industry level averages as follows:

$$\widetilde{\sigma}_j = \left(\frac{1}{N_I} \sum_{i \in I} \sum_{t \in T} s_{j,it} \right)^{-1} \frac{1}{N_I} \sum_{i \in I} \sum_{t \in T} (r_{it} + \delta^I_{j,t}) \tag{23}$$

and

$$\widetilde{\rho}_j = \left(\frac{1}{N_I} \sum_{i \in I} \sum_{t \in T} oi_{j,it} \right)^{-1} \frac{1}{N_I} \sum_{i \in I} \sum_{t \in T} (r_{it} + \delta^I_{j,t}) \tag{24}$$

where j indicates the type of capital good; I denotes industry (there are N_I firms in an industry); $\delta^I_{j,t}$ is the rates of physical depreciation; r_{it} is the interest on financial debt divided by the stock of debt. Table A.4.1 in the appendix reports the computed values of σ and ρ.

In estimating equation 17, we also include a vector of time dummies which capture aggregate shocks, d_t. We apply a GMM methodology and use first differences to eliminate the individual firm effects. As shown in 19 and 20, we construct three fundamental Q's, one for each type of capital good. The VAR(2) estimates are reported in the appendix (Tables A.5.1 and A.5.2).

In the second stage we use the fundamental Q's from the first stage and estimate three investment equations, for homogeneous capital, equipment and structures. We again adopt a GMM and apply first differences in order to eliminate the individual effects which are likely to be correlated with the lagged values of operating income and sale rates. The instruments used are lagged values of operating income and sales (up to two-period and in levels) and time dummies. [12] The estimation period is 1987-1995.

First-step GMM estimates of net investment expenditures (purchases - sales) for aggregate capital, equipment and structures under the assumption of perfect competition (see equation 15) are reported in Table 5.[13]

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[12] Estimation was performed using DPD for Ox (Arellano, Bond and Doornik, 1999).

[13] In the one-step GMM estimator the weighting matrix is a square matrix that has 2 on the main diagonal, -1 on the first subdiagonals and 0 everywhere else. In the two-step GMM estimator the weighting matrix starts from the one-step residuals. The weighting matrix for the instruments is given by the squared sum of the one-step residuals. If the residuals are heteroscedastic, then the two-step GMM estimator is more efficient (White, 1982). Simulation exercises have shown that the asymptotic standard errors for the two-

Table 5 Net Investment (Purchases - Sales)

	Coefficients		
	(1)	**(2)**	**(3)**
	Aggregate	**Equipment**	**Structures**
Q	0.174**	0.447**	0.101
	(0.039)	(0.087)	(0.062)
no. of observations	13851	13851	13851
Sargan $\chi 2$	67.58**	33.56	64.13**
AR(1) N(0,1)	-12.98**	-13.35**	-15.24**
AR(2) N(0,1)	-5.15**	0.81	1.33

Estimates of time dummies coefficients not reported;
standard errors in parentheses;
* and ** imply a 5% and 1% level of significance respectively.

The table shows that investment responds positively to fundamental Q. If we look at the single aggregate Q case, we see that the estimated coefficient is positive and significant.[14] If we compare our estimate with the coefficients obtained in the literature on Q, we find that it tends to be higher than those in previous studies (see Withed, 1994, and more recently Abel and Eberly, 1999). However, the Sargan test, obtained in the second stage estimation, and the test for second order serial correlation indicate that there may be problems with this specification. Is the assumption of capital homogeneity the culprit? Columns 2 and 3 in the table clearly indicate that it is very important to allow for heterogeneity among capital goods. Indeed column 2 shows that investment in equipment may be adequately represented by the traditional linear relationship between investment and Q. On the contrary, the model estimated in column (3) shows that the fundamental Q fails to explain investment in structures.

step estimation are not reliable because they are affected by a downward finite sample bias. Inference based on the one-step standard errors is more robust, as suggested by Arellano and Bond (1991).

[14] We are aware of the fact that the standard errors of the fundamental Qs in our estimated equations are not adjusted for the fact that the present value terms have been estimated in a previous regression. Gilchrist and Himmelberg (1998) note that when this adjustment is made standard errors are increased by approximately 75-100%. Even if we adopt this criterion, our conclusions continue to hold.

The coefficient on the Q for equipment is significant and equal to 0.447, markedly higher than that on aggregate investment, and is consistent with the hypothesis of quadratic adjustment costs. The Sargan test fails to reject the validity of the instruments. The consistency of our estimates relies upon the hypothesis of absence of serial correlation in the error terms in the level equation. If the error terms are not serially correlated there should be evidence of significant negative first-order correlation but absence of second order correlation in the differenced residuals.[15] The tests AR(1) and AR(2) reported in the table are consistent with the hypothesis of absence of second-order serial correlation and significant first order correlation. This confirms our finding that the behavior of equipment investment is consistent with the standard modelling practice based on convex adjustment costs.

The picture for structures, instead, is quite different. In this case, reported in column 3, the linear relationship between investment and fundamental Q breaks down. The coefficient on fundamental Q is not significant and the Sargan test rejects the validity of the instruments. The hypothesis of convex adjustment costs does not appear to hold. From the descriptive analysis of Tables 1, 3 and 4, we know already that structures show a high frequency of zero investment, and this implies the possibility of fixed components in the structure of adjustment costs and a non-linear relation between investment and Q. Recent studies (Abel and Eberly, 1999; Barnett and Sakellaris, 1998) show that fixed components in the structure of adjustment costs and partial irreversibility are likely to affect investment behavior. If this is the case, aggregation over different capital goods fails to account for differences in adjustment costs by smoothing out the adjustment paths. However, none of the above recent studies have focused on heterogeneous capital inputs.[16]

Finally, all the equations in Table 5 were estimated with time dummies in order to control for common aggregate shocks, changes in the law and price variations in each capital good. The estimated coefficients, not reported in this and the following tables, capture in all the equations the significant effect on investment of the recession which occurred in 1991-1993 and of the boost

[15] Moreover, lack of second order correlation in the differenced residuals may be due to both absence of serial correlation and a random walk process followed by the errors in levels. Negative first correlation in the differenced residuals allows us to discriminate between these two cases.

[16] See also Goolsbee and Gross (1997) for an estimation of adjustment costs with data on heterogeneous capital goods, even though the results reported refer to a single capital index.

in investment generated by the "Tremonti law".[17]

Table 6 reports estimates in the case of gross investment. This allows us to estimate separately purchases and sales of equipment and structures.

Table 6 Gross Investment: Purchases and Sales

	Coefficients		
	(1)	**(2)**	**(3)**
	Aggregate	**Equipment**	**Structures**
Purchases			
Q	0.163**	0.399**	0.095
	(0.041)	(0.090)	(0.064)
no. of observations	13851	13851	13851
Sargan χ^2	56.23*	26.75	58.78**
AR(1) N(0,1)	-6.23**	-9.64**	-7.66**
AR(2) N(0,1)	-1.86	0.75	1.02
Sales			
Q	-0.011	-0.047	-0.006
	(0.017)	(0.039)	(0.011)
no. of observations	13851	13851	13851
Sargan χ^2	24.75	35.64	35.80
AR(1) N(0,1)	-3.43**	-4.16**	-2.79**
AR(2) N(0,1)	0.15	-0.32	1.01

Estimates of time dummies coefficients not reported;
standard errors in parentheses;
* and ** imply a 5% and 1% level of significance respectively.

The results for purchases of capital, reported in the first panel of the table, show that the Q coefficient is statistically significant in the case of equipment but not in the case of structures, which are characterized by a much higher number zeros (16.8 percent of observations showing zero investment in structures against 2.8 percent in the case of equipment). As in the case of net investment, the estimates in column (1) show that when we aggregate over

[17] Firms which in 1994-1995 were investing an amount greater than the average over the previous five years were entitled to a 50% tax reduction on the excess.

capital goods the specification based on fundamental Q performs much more poorly.

In the second panel of Table 6 we report the estimated equations in the case of sales of capital goods or disinvestment. From Table 1 in Section 4, it will be recalled that pure zero sales are very frequent in all types of goods, reaching the highest percentage, 42.66, in the case of structures. The descriptive evidence suggests that, given the high frequency of zeros, we should expect a weaker relationship between disinvestment and Q than in the case of pure purchases. Table 6 shows that, although the coefficient on fundamental Q is correctly signed, in none of the equations is it statistically significant. This implies that the high number of zeros should be taken explicitly into account and that the standard strictly convex adjustment cost specification may not be appropriate when we look at sales of capital goods.[18]

As a final step, in order to consider further the presence of zeros in the case of disinvestment we estimate a tobit model with censoring at zero. This allows to consider the discrete choice (reduce the capital stock or leave it unchanged) and exploit at the same time the information contained in the observed outcomes. We write:

$$y_{it} = \begin{cases} y^*_{it} & if \quad y^*_{it} < 0 \\ 0 & otherwise \end{cases} \tag{25}$$

where y^*_{it} is the latent dependent variable measuring the amount the firm is willing to disinvest at time t with:

$$y^*_{it} = b' FQ_{it} + \varepsilon_{it} \qquad \varepsilon_{it} \sim \left(0, \sigma^2\right) \tag{26}$$

where FQ_{it} is the fundamental Q and where time dummies are omitted but included in estimation among the explanatory variables. We observe $y_{it} = y^*_{it}$ only if the firm decides to disinvest ($y^*_{it} < 0$); otherwise we observe zero. The evidence is reported in Table 7.

[18]We have also estimated the same equations under the assumption of an imperfectly competitive product market using the methodological appartus previously expounded. We do not report the results to conserve on space. The estimation results are not so clear cut as they are in the case of perfect competition. While we consider more appropriate this last specification, the results under imperfect competition remain broadly consistent with the ones presented here.

Table 7 Sales of Capital Structures: Tobit Estimates

	Coefficients: (1) Aggregate	(2) Equipment	(3) Structures
Q	-0.004	0.011	-0.034
	(0.007)	(0.008)	(0.008)
no. of observations	15390	15390	15390
censored obs.	3646	4057	6043
uncensored obs.	11744	11333	9347
log-likelihood	625.6	-2092.9	-5727.8

All variables in levels; estimates of time dummies coefficients not reported; robust standard errors in parentheses.

The results are obtained assuming that the processes which determine the selection equation (whether or not to reduce the capital stock) and the disinvestment equation (conditional on the decision to disinvest) are identical. To overcome this limitation one should explicitly model the selection process and adopt a two stage procedure or better directly model the discrete decision. We do not go that far. Our purpose here is simply to focus on the ability of the fundamental Q model to predict the occurrence as well as the amount of disinvestment for each capital good. It emerges that fundamental Q has a significant negative effect in the case of structures, where the incidence of the censored observation is very high (65%) while it is not significant either for equipment or aggregate capital, the correct negative sign in the latter case notwithstanding. These results imply that, in the case of structures, disinvestment is better explained by a censored model and this is in line with the fact that adjustment costs may be, at least to some extent, independent of the level of investment. This simple descriptive exercise confirms our findings in Tables 5 and 6 according to which, in the case of structures, the linear relationship between investment and fundamental Q breaks down. Further analysis requires modelling the presence of zeros within a more structural setup and this is beyond the scope of the present paper.

6 Conclusions

In this paper we have studied the investment decisions of individual firms by abandoning the assumption of a single capital good. This is rarely done in the literature of investment. We have exploited a newly developed panel dataset, on small and medium firms, which allows the capital assets to be disaggregated in various categories.

We have modelled investment choices in different capital inputs building upon under the assumption of convex costs of adjustment. To assess the performance of empirical investment equations under capital heterogeneity using data on non quoted individual firms we have used a fundamental Q approach. This captures the firm's investment opportunities and generalizes to the case of two capital inputs the approach originally suggested by Abel and Blanchard (1986) and by Gilchrist and Himmelberg (1995).

Recent developments in the literature have studied investment decisions departing from the assumption of reversibility and of convex adjustment costs. This analysis has been initially conducted at the theoretical level and only subsequently has moved to empirical grounds. The assumption of capital homogeneity has however somewhat limited the scope of those economtric investigations. While it is certainly true that aggregation tends to hide important possible nonconvexities, it is similarly true that dilute existing convexities. In the light of thiese considerations we have chosen to base the anaysis of investment decisions in several capital inputs done in this paper on the traditional assumption of convex costs of adjustment. We believe that in so doing we have filled a gap until now present in the literature.

The results are interesting, in that they generally show the standard convex costs model explains well equipment but not structures. Our findings reject the convexity hypothesis at least for individual capital types and motivate our next research steps along two main avenues. The first ought to extend the analysis to other capital inputs, in particular to intangible capital (R&D, advertising, and the like); the second should pursue the empirical study of nonconvexities using fundamental Qs under capital heterogeneity.

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A Appendix

A.1 Variable Specification

- **Aggregate variables**

δ_T, δ_E, δ_S: depreciation rates of total fixed assets, equipment and structures by year and 2-digit manufacturing industry.

p_T, p_E, p_S: price indexes for investment in total assets, equipment and structures by year and 2-digit manufacturing industry (1995=1), (source: ISTAT)

pp: output price index for the 13 sub-sectors of the manufacturing industry. This price index is normalized to unity for 1995, (source: ISTAT);

π: output price rate of inflation (1995=1), (source: ISTAT)

τ: corporate tax rate on firm profits (equal to 46.368% in 1985-1990; 47.826% in 1991, 52.2% in 1992-1994; and 53.2% in 1995.

- **Firm-specific variables:**

  r: interest expenses on bank loans, factoring and leasing (ie the actual interest rate) divided by the corresponding stock of debt.

$\widetilde{K}_T$,$\widetilde{K}_E$, $\widetilde{K}_S$: end of period book values of gross total fixed assets, plant+ machinery+equipment, and land+ buildings, respectively. Total fixed assets are equal to the sum of plant, machinery, equipment, land and buildings.

$N\widetilde{K}_T, N\widetilde{K}_E, N\widetilde{K}_S$: end of period book values of net total fixed assets, plant, machinery/equipment and land/buildings. For period 1991-95, the book values of both gross and net capital goods are available in the dataset. For period 1982-1990, we only have book values of gross equipment and structures; the disaggregated book values of net capital goods are obtained by subtracting the corresponding share of book value of accumulated depreciation.

I^+_T, I^+_E, I^+_S: capital expenditures on total fixed assets, equipment and structures. This measure includes only direct purchases of new fixed assets and it does not include fixed assets acquired through takeovers and acquisitions.

I_T^-, I_E^-, I_S^-: sales of total fixed assets, equipment and structures. These variables measure the sale value, and not the historical cost, i.e. it amounts to the remaining book value of sold assets (acquisition minus the book value of accumulated depreciation of assets that are sold or dismissed during the year) plus the difference between the historical acquisition cost and the market price of the sale.

Given that we only have aggregated purchases and sales, we use the method proposed by Bond and Meghir (1994) in order to obtain disaggregated investment and disinvestment. We use the change in gross fixed assets to estimate purchases and sales of plant and land according to:

$$I_{E,t}^+ = I_{T,t}^+ \frac{\widetilde{K}_{E,t} - \widetilde{K}_{E,t-1}}{\widetilde{K}_{T,t} - \widetilde{K}_{T,t-1}}$$

where E indicates equipment, subscript T refers to total investment or capital and t and $t-1$ are time subscripts.

Gross investment in structures is obtained by the difference:

$$I_{S,t}^+ = I_{T,t}^+ - I_{E,t}^+$$

The same procedure applies to the case of sales, $I_{E,t}^-$ and $I_{S,t}^-$.

I_T, I_E, I_S: net investment in total fixed assets, equipment and structures. Net investment is computed as the difference between direct purchases and sales of capital goods.

K_T, K_E, K_S: replacement cost values of total fixed assets, equipment and structures. These values are estimated from historic cost accounts by using an iterative perpetual inventory formula, modified in order to take into account the " *Visentini Law*", which allowed firms to revalue the book values of their capital stock in 1982 and 1983. Thus, to obtain starting values for the iterative procedure we adopt the following rule:

1. we assume that the replacement cost values are equal to the historic cost values in 1982 if firms chose to revalue in 1982 or if they did not revalue at all.

2. otherwise we consider 1983 the starting year if companies revalue their capital stock in 1983.

The use of the revalued historic cost allows us to only drop the first two years for estimation purposes, whereas it is standard in the literature to drop the first three years. The iterative perpetual inventory formula used to calculate the replacement cost valuation of each type of capital are the following:

$$K_{j,t+1} = K_{j,t}\left(1 - \delta_{j,t+1}\right)\left(p_{j,t+1}/p_{j,t}\right) + I_{j,t+1}$$

where $j = T, E$ and S and the initial K_j is equal to the net book value of capital good j in 1982 or 1983.

Investment and capital stocks are all expressed at constant prices using the relevant price indices $\mathrm{p}_j, p_{j,t}/p_{j,t+1}$, $j = T, E, S$.

S_T, S_E, S_S: real sales as a proxy for the nominal value of output deflated by the output price index, pp, disaggregated at 2-digit industry level.

OI_T, OI_E, OI_S: operating income as a proxy for marginal product of capital, deflated by the output price index, pp, disaggregated at 2-digit industry level. Operating income is defined as: income before depreciation allowances, financial and extraordinary items, discontinued operations, taxes, and preference dividends.

Variables $I_T, I_E, I_S, S_T, S_E, S_S, OI_T, OI_E, OI_S$ are all divided by the stock at replacement cost of the relevant capital good one-period lagged.

A.2 Cleaning Criteria

We have a balanced data on manufacturing companies with a 12-month balance-sheet of 5.086 companies. The final dataset we obtained after cleaning the data is a balanced panel of 1,539 manufacturing companies for period 1985-1995. Our trimming rules were the following:

- We eliminate firms with missing data on: aggregated and disaggregated capital stock at the beginning of the sample period, sales, and operating income. This eliminates 37.30% of the firms.
- Firms with negative replacement values of the capital stock are also eliminated since they are generated when net investment is greater than lagged capital stock as a consequence of large sales of capital goods. This criterion implies an additional loss of 23.43% of companies.
- In order to minimize measurement errors we only consider: investment rates between -1% and 5%; ratio of real output to capital between 20% and 150%; operative earnings between -50% and 75% of sales; marginal productivity of capital between -27% and 127.5%. These final criteria cuts 9% of companies. Elimination of strong outliers is necessary for disaggregating investment. Our procedure uses changes in gross capital stocks: these include not only investment but also mergers, acquisitions, divestitures, selloffs and other miscellaneous transactions.

A.3 The Dataset

The sample includes 1539 firms over the period 1982-1995. In Table A1.1 we show the distribution of firms by 2-digit industry (Source: Italian Statistical Office - ISTAT) and the distribution of firms by size.

Table A.3.1 Distribution of Firms by Industry and Size

Industry	**No. of firms**	**Frequency**
Food, drinks and tobacco	167	10.85
Textile and clothing	177	11.5
Leather and footwear	31	2.01
Timber and wooden furniture	34	2.21
Paper and printing	82	5.33
Oil, chemicals and fibres	128	8.32
Rubber and plastic	101	6.56
Minerals	116	7.54
Metal and metal goods	108	7.02
Mechanical engineering	384	24.95
Electric materials and precision instrum.	93	6.04
Motor vehicles and other transport equip.	36	2.34
Other manufacturing	82	5.33
Size		
0-49	454	29.71
50-259	875	57.26
$\geq$250	199	13.02

In Tables A.3.2 and A.3.3 we show the frequency of zero and negative net investment by sectors and size.

Table A.3.2 Zero Net Investment by Industry and Size

Industry	**Total**	**Equipment**	**Structures**
Food, drinks and tobacco	0.16	0.22	10.45
Textile and clothing	0.51	0.56	16.90
Leather and footwear	0.59	0.88	26.39
Timber and wooden furniture	0.53	0.53	10.43
Paper and printing	0.33	0.33	11.09
Oil, chemicals and fibres	0.50	0.64	11.43
Rubber and plastic	0.27	0.36	11.16
Minerals	0.71	0.78	11.68
Metal and metal goods	0.17	0.25	10.10
Mechanical engineering	0.59	0.73	16.93
Electric materials and precision instruments	0.39	0.39	15.25
Motor vehicles and other transport equip.	-	- -	16.16
Other manufacturing	0.22	0.33	10.86
Size			
0-49	0.56	0.72	18.84
50-249	0.43	0.50	2.09
≥250	0.14	0.14	1.92

Table A.3.3 Negative Net Investment by Industry and Size

Industry	**Total**	**Equipment**	**Structures**
Food, drinks and tobacco	2.34	10.18	11.38
Textile and clothing	2.77	10.73	11.66
Leather and footwear	3.23	8.21	12.90
Timber and wooden furniture	2.94	11.23	10.43
Paper and printing	3.10	9.42	11.31
Oil, chemicals and fibres	2.20	9.16	11.79
Rubber and plastic	2.97	9.99	12.69
Minerals	2.12	9.01	13.48
Metal and metal goods	2.02	8.42	10.10
Mechanical engineering	2.32	9.16	11.91
Electric materials and precision instruments	1.27	6.74	12.02
Motor vehicles and other transport equip.	3.03	9.60	10.86
Other manufacturing	1.88	8.87	11.42
Size			
0-49	3.08	9.99	11.69
50-249	2.09	9.06	11.54
≥250	1.92	8.95	12.88

Null net investment is high in "Leather and footwear", and "Mechanical engineering" if we consider total fixed assets and structures; null net investment in structures is relatively high also in "Textile" and "Motor vehicles"; this last sector dose not show null net investment in plant. Disinvestment in plant has a relatively higher incidence in "Food", "Textile" and "Timber"; disinvestment in land is higher in "Leather", and "Rubber and plastics".

A.4 Calculation of σ_j and ρ_j at the Industry Level

Table A.4.1 Estimates of σ and ρ by industry

	σ			ρ		
Industry	**Agg.**	**Eq.**	**Str.**	**Agg.**	**Eq.**	**Str.**
Food, drinks and tobacco	0.046	0.028	0.013	0.617	0.380	0.166
Textile and clothing	0.069	0.038	0.020	0.660	0.372	0.184
Leather and footwear	0.051	0.034	0.14	0.647	0.440	0.170
Timber and wooden furniture	0.095	0.055	0.027	0.844	0.495	0.231
Paper and printing	0.088	0.063	0.021	0.753	0.541	0.174
Oil, chemicals and fibres	0.051	0.032	0.018	0.478	0.300	0.156
Rubber and plastic	0.082	0.049	0.022	0.712	0.425	0.190
Minerals	0.101	0.066	0.024	0.754	0.499	0.179
Metal and metal goods	0.072	0.047	0.020	0.701	0.468	0.193
Mechanical engineering	0.064	0.036	0.019	0.578	0.325	0.167
Electric materials and precision instruments	0.065	0.039	0.018	0.479	0.286	0.131
Motor vehicles and other transport equip.	0.064	0.038	0.015	0.587	0.333	0.137
Other manufacturing	0.072	0.040	0.024	0.763	0.422	0.260

A.5 VAR(2) Estimation

Estimation is in first differences. Instruments are time dummies and lagged values (two and three lags) of operating income (oi) and sales (s).

Table A.5.1 VAR(2): Operating income

Variables	**Coefficients**		
	(1)	**(2)**	**(3)**
	Aggregate	**Equipment**	**Structures**
$oi(-1)$	0.691**	0.588**	0.654**
	(0.040)	(0.057)	(0.064)
$oi(-2)$	-0.029	-0.055	-0.020
	(0.023)	(0.041)	(0.0387
$s(-1)$	0.018	-0.071	0.101
	(0.048)	(0.076)	(0.079)
$s(-2)$	-0.104*	0.006	-0.081
	(0.038)	(0.055)	(0.069)
no. of observations	12312	12132	12312
Sargan χ^2	31.32	48.35**	40.51
AR(1) N(0,1)	-12.87**	-5.51**	-7.39**
AR(2) N(0,1)	0.40	0.18	1.03

Time dummies not reported; standard errors in parentheses;
* and ** imply a 5% and 1% level of significance respectively.

Table A.5.2 VAR(2): Sales

Variables	**Coefficients**		
	(1)	**(2)**	**(3)**
	Aggregate	**Equipment**	**Structures**
$oi(-1)$	0.016	-0.008	-0.013
	(0.022)	(0.037)	(0.033)
$oi(-2)$	-0.001	-0.021	0.009
	(0.015)	(0.034)	(0.025)
$s(-1)$	0.816**	0.636**	0.824**
	(0.043)	(0.081)	(0.058)
$s(-2)$	-0.133**	-0.064	-0.059
	(0.032)	(0.057)	(0.047)
no. of observations	12312	12132	12312
Sargan χ^2	50.89	60.66**	46.38*
AR(1) N(0,1)	-8.46**	-6.48**	-7.35**
AR(2) N(0,1)	-0.24	0.86	0.98

Time dummies not reported; standard errors in parentheses;
* and ** imply a 5% and 1% level of significance respectively.

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