Programa de Investigaciones Económicas
FUNDACION EMPRESA PUBLICA. Pza. Marqués de Salamanca, 8. 28006 Madrid.
Tf.: 91 577 79 45 - 577 79 48 ; Fax: 91 575 56 41

Documento de Trabajo
9902

Factor Demands and Innovation Activity: Evidence from Spanish Manufacturing Firms

César Alonso-Borrego*
M. Dolores Collado**

March 1999

* Universidad Carlos III de Madrid
Dpto. de Estadística y Econometría
c/ Madrid, 126
28903 - Getafe (Madrid)
e-mail: alonso1@est-econ.uc3m.es

** Universidad de Alicante
Facultad CC.EE.
Dpto. Fundamentos del Análisis Económico
Crtra. San Vicente, s/n
03080 - San Vicente (Alicante)
e-mail: collado@merlin.fae.ua.es

Research funded by Fundación Empresa Pública and by the Spanish DGES, reference PB95-0292, is acknowledged.

Factor Demands and Innovation Activity: Evidence from Spanish Manufacturing Firms*

César Alonso-Borrego
Universidad Carlos III de Madrid

M. Dolores Collado
Universidad de Alicante

March 1999

Abstract

In this paper we address the estimation of Euler equations for labour and capital inputs, using an adjustment cost schedule which allows for interactions between capital and labour and for asymmetries between positive and negative adjustments. Furthermore, we allow factors productivity to depend on the innovation activity undertaken by the firm. Our results, based on a sample of Spanish manufacturing firms for the period 1991-1995, can be summarized as follows. We find evidence of p-substitutability between capital and labour. Furthermore, we find a positive effect of innovative activity on labour productivity.

Key words: Factors demand; Adjustment costs; Innovation; Dynamic panel data.
JEL classifications: C33; J21; J44; L23.

*Research funded by Fundación Empresa Pública and by the Spanish DGES, reference PB95-0292, is acknowledged.

1 Introduction

In the study of intertemporal models of factor demands under adjustment costs, the use of Euler equations and the assumption of rational expectations make possible to derive empirical equations that entail the parameters of interest. On the one hand, costs of adjustment allow to rationalize the empirical evidence of sluggishness in stock adjustment. On the other hand, the rational expectations assumption yields a direct justification on how expectations on future values are determined by the firm.

However, Euler equation models are very often rejected by the data. This rejection is generally apparent because of the values of specification tests (e.g., high values of the Hansen-Sargan test, evidence of correlated residuals, etc.), or because the estimated values of the parameters are found to be implausible. Particularly, the estimated value of the discount rate does often take implausible values, ranging from incredibly high discount rates that imply myopic firm behaviour, to negative discount rates. Moreover, the source of misspecification is not clearly identified. One of the obvious reasons for model misspecification is the lack of a flexible parameterization. In fact, very often the Euler equations depend on a few parameters that involve strong restrictions.

This paper examines the determinants of the demands for labour and capital inputs in an intertemporal framework under rational expectations. To understand factor decisions taken by firms, it is very important to take account of the adjustment costs that are behind these decisions (see Hamermesh and Pfann (1996) for a survey on the theoretical and empirical literature on adjustment costs). In line with Nadiri and Rosen (1969), Pindyck and Rotemberg (1983) and Palm and Pfann (1990) among others, we derive optimal factor decisions based on the first order conditions for profit-maximizing firms that face costs of adjusting factors and have rational expectations on future realizations of the state variables. We extend the standard model on two grounds. First, we account for the influence of innovation activity on factors demand. Second, we adopt a more flexible parameterization for adjustment costs.

Although technological innovation is considered as a primary source of economic growth, there are not many empirical examples that consider mechanisms by which innovation affect firms factor decisions. One of the notable exceptions is due to Meghir, Ryan and Van Reenen (1996), who examine the impact of technological change on net job creation in a structural model of labour demand, finding that innovation-intensive firms face lower adjustment costs that firms which do not innovate. Here we consider a different approach, allowing factor productivity to depend on the level of innovation activity undertaken by the firm.

Our specification allows for interaction between capital and labour adjustments, and for asymmetries between positive and negative adjustments. We then rule out the usual assumption of separability in adjustment costs among different labour inputs. In addition, we account for the fact that for a given magnitude of adjustment, the costs of increasing an input does not need to coincide with the costs of reducing such input by the same amount. Our specification here is in line with Bresson, Kramarz and Sevestre (1991) and Alonso-Borrego (1998), among others, who account for asymmetric and interrelated adjustment costs for heterogeneous labour inputs. Our approach consists on a more flexible alternative to the usual adjustment cost specification. Although the most flexible approach would consist on a nonparametric specification for adjustment costs, as Delgado and Jaumandreu (1998) develop in the case of the demand for a single labour input, we restrict ourselves to a parametric specification, since a nonparametric approach would become cumbersome in the two-inputs case.

We confirm our conjecture that the assumption of adjustment cost separability between labour and capital is rejected by the data. Our main results show significant evidence of p-substitutability between labour and capital. In addition, we find a significant and positive effect of innovation on labour productivity.

The paper is organized as follows. In section 2 we present a simple dynamic model of labour and capital decisions under rational expectations and discuss the specifications for technology and adjustment costs. In section 3 we describe the data and the econometric approach. In section 4 we discuss the results and we summarize the main findings in section 5.

2 The model

2.1 Basic framework

Consider a firm that uses homogeneous labour and fixed capital as inputs and chooses hirings and gross investment in fixed capital to maximize its expected net present value of current and future profits

$$V_t(s_{t-1}) = \max_{H_t, I_t} \left\{ \Pi(s_{t-1}, H_t, I_t) + \beta E_t \left[V_{t+1}(s_t) \right] \right\}, \tag{1}$$

where $s_t = (L_t, K_t)'$ is the vector of the stocks of labour and capital inputs at the end of period t, H_t and I_t are the hirings of workers and the investment in fixed capital stock, $\beta \in (0,1)$ is the discount factor (assumed to be constant over time), and $E_t[\cdot] = E[\cdot| \ _t]$ is the conditional expectation operator given the information set $\ _t$ available to the firm at period t. The stocks of labour and capital inputs evolve over time according to the laws of accumulation

$$L_t = L_{t-1} + H_t \tag{2}$$

$$K_t = (1-\delta)K_{t-1} + I_t \tag{3}$$

The first order conditions for the optimization problem (1) are given by

$$\frac{\partial V_t}{\partial H_t} = 0 \Rightarrow \frac{\partial \Pi_t}{\partial H_t} + \beta E_t \left(\frac{\partial V_{t+1}}{\partial L_t} \right) = 0 \tag{4}$$

$$\frac{\partial V_t}{\partial I_t} = 0 \Rightarrow \frac{\partial \Pi_t}{\partial I_t} + \beta E_t \left(\frac{\partial V_{t+1}}{\partial K_t} \right) = 0 \tag{5}$$

Using the envelope theorem, we have that

$$\frac{\partial V_t}{\partial L_{t-1}} = \frac{\partial \Pi_t}{\partial L_{t-1}} + \beta E_t \left(\frac{\partial V_{t+1}}{\partial L_t} \right) \tag{6}$$

$$\frac{\partial V_t}{\partial K_{t-1}} = \frac{\partial \Pi_t}{\partial K_{t-1}} + \beta (1-\delta) E_t \left(\frac{\partial V_{t+1}}{\partial K_t} \right) \tag{7}$$

Then, combining (4), (6), and (5), (7), respectively, to eliminate $\partial V_{t+1}/\partial L_t$, $\partial V_{t+1}/\partial K_t$, we obtain:

$$-\frac{\partial \Pi_t}{\partial H_t} = \beta E_t \left(\frac{\partial \Pi_{t+1}}{\partial L_t} - \frac{\partial \Pi_{t+1}}{\partial H_{t+1}} \right) \tag{8}$$

$$-\frac{\partial \Pi_t}{\partial I_t} = \beta E_t \left[\frac{\partial \Pi_{t+1}}{\partial K_t} - (1-\delta) \frac{\partial \Pi_{t+1}}{\partial I_{t+1}} \right] \tag{9}$$

2.2 Parameterizations

The pro t function can be written as

$$\Pi(L_t, K_t, H_t, I_t) = p_t F(L_t, K_t) - p_t AC(H_t, I_t, L_{t-1}, K_{t-1}) - w_t L_t - q_t I_t \tag{10}$$

where p_t, w_t, and q_t denote the prices of output, and labour and capital inputs respectively; $F(\cdot)$ is the gross production function and $AC(\cdot)$ is the adjustment costs function associated to hirings and investment, which is de ned in terms of output loss (so that $\widetilde{Y}_t = F(\cdot) - AC(\cdot)$ can be interpreted as net output).

To get explicit forms for the Euler equations, we have to make some assumptions on the functional forms of technology and adjustment costs. For the technology $F(L_t, K_t)$, we will assume a translog speci cation:

$$\begin{aligned} F(L_t, K_t) = \; & \exp\Big\{ \alpha^0 + \alpha_t^L \ln L_t + \alpha_t^K \ln K_t + \alpha^{LL} (\ln L_t)^2 \\ & + \alpha^{KK} (\ln K_t)^2 + \alpha^{LK} (\ln L_t)(\ln K_t) \Big\} \end{aligned} \tag{11}$$

where for any particular rm the coefficients on $\ln L_t$ and $\ln K_t$ are allowed to vary over time in order to recognize that factors productivity may depend on the innovation activity that the firm undertakes:

$$\alpha_t^j = \alpha^j + \alpha^{jR} \ln R_t \quad (j = K, L) \tag{12}$$

where R_t is the stock of R&D capital in period t.

Our specification for adjustment costs takes account of asymmetries between positive and negative adjustment in labour and capital, and it also recognizes the possibility of p-substitution (see Hamermesh, 1993, ch. 6) by means of cross-effects between labour and capital:

$$\begin{aligned} AC(H_t, I_t, L_{t-1}, K_{t-1}) \quad = \quad & \frac{b_{2L}}{2}\left(\frac{H_t}{L_{t-1}}\right)^2 L_{t-1} + \frac{b_{3L}}{3}\left(\frac{H_t}{L_{t-1}}\right)^3 L_{t-1} \\ & + \frac{b_{2K}}{2}\left(\frac{I_t}{K_{t-1}}\right)^2 K_{t-1} + \frac{b_{3K}}{3}\left(\frac{I_t}{K_{t-1}}\right)^3 K_{t-1} \\ & + b_{LK}\, \frac{H_t}{L_{t-1}}\, \frac{I_t}{K_{t-1}} \left(L_{t-1}K_{t-1}\right)^{1/2} \end{aligned} \tag{13}$$

3 Data and econometric issues

3.1 Data sources and descriptive statistics

The main data set is an unbalanced panel of 968 Spanish manufacturing firms, recorded in the database *Encuesta Sobre Estrategias Empresariales* (Survey on Companies Strategies, after this, ESEE) during the period 1991-1995 (see Data Appendix for a description of these data). This data set contains information on labour and capital inputs, and investment on physical capital and R&D. The advantage of the ESEE database is that it has been designed to accomplish a representative sample of Spanish manufacturing.

In Table 1 we summarize firms R&D investment in 1993 by 2-digits industry. In column 1, we report the mean of the R&D intensity by industry for the firms in our sample. Not surprisingly, R&D intensity is very different across industries, and the most R&D-intensive are Electronics and Motor Vehicles. In columns 2 and 3, we report the absolute and relative frequencies of firms with positive R&D investment by industry in 1993. Again, the industries with the highest proportion of firms investing in R&D are Electronics and Motor Vehicles, followed closely by Chemicals and Electric Materials.

In Table 2 we present some descriptive statistics by year. Gross job creation and destruction rates have been calculated following Davis and Haltiwanger (1992). We observe a net lost of jobs in manufacturing industries along the period, the loss being more pronounced in 1992 and 1993. The Spanish economy suffered from a recession which finishes around 1994, and the behaviour of employment in manufacturing industries reflects this phase of the economic cycle. The net job destruction rates obtained from our sample are quite similar to the aggregate figures derived from the Labour Force Survey. The rate of growth of value added in manufacturing firms also reflects the economic cycle, and the figures we obtain resemble the aggregate figures from the industrial production indices. Finally, we can mention that investment in fixed capital does not seem to depend on productivity shocks faced by the firms.

3.2 Econometric issues

The Euler equations given by (8) and (9) include conditional expectations of functions of forward variables, which are unknown at period t, but we could substitute them by their actual values plus an expectational error. Under rational expectations, and in the absence of measurement errors and autocorrelated shocks, the conditional expectation at period t of such expectational errors is zero. Hence, we can rewrite the Euler equations above as

$$\beta \frac{\partial \Pi_{t+1}}{\partial L_t} - \beta \frac{\partial \Pi_{t+1}}{\partial H_{t+1}} + \frac{\partial \Pi_t}{\partial H_t} = \varepsilon_{t+1}^{L} \quad (14)$$

$$\beta \frac{\partial \Pi_{t+1}}{\partial K_t} - \beta(1-\delta) \frac{\partial \Pi_{t+1}}{\partial I_{t+1}} + \frac{\partial \Pi_t}{\partial I_t} = \varepsilon_{t+1}^{K} \quad (15)$$

where $E_t(\varepsilon^L_{t+1}) = E_t(\varepsilon^K_{t+1}) = 0$. The parameters of interest are identi ed by a set of moment conditions, where any variable included in the information set will be a valid instrument. We will thus estimate the empirical Euler equations (14) and (15) using GMM.

Since our data on investment is referred to gross investment (purchases of xed capital), the range of this decision variable is bounded below. Therefore, the optimization problem can yield corner solutions for some rms. In fact, we observe a signi cant proportion of rms with zero investment in particular periods. The Euler equation for capital is not valid for these observations, because such equations characterize the interior solutions to the optimization problem. Our estimation approach will thus consist in selecting the subsample of observations with positive investment. We will thus condition our sample on the event $D_{it} = 1(I_{it} > 0) = 1$, where $1(\cdot)$ is the indicator function, which takes value one if the condition is true and zero otherwise. Although as mentioned above the error term for the capital equation satis es that $E_t[\varepsilon^K_{t+1}] = 0$, this orthogonality condition is no longer satis ed when we restrict to the event $D_{i,t+1} = 1$, so that $E_t[\varepsilon^K_{t+1}|D_{i,t+1} = 1] \neq 0$. Letting $\Pr[D_{i,t+1} = 1|\ _{it}] = \Pr[\pi'_{t+1} Z_{it} + \nu_{i,t+1} > 0]$, where Z_{it} is a vector of variables included in the information set at t, and assuming that the error term $\nu_{i,t+1}$ is normally distributed, then

$$E_t[\varepsilon^K_{t+1}|D_{i,t+1} = 1] = \sigma\lambda(-\pi'_{t+1} Z_{it}) \tag{16}$$

where $\lambda(\cdot)$ is the inverse of the Mills ratio, de ned as the ratio of the density function to the cumulative distribution function of the standard normal. Although $\lambda_{it} = \lambda(-\pi'_{t+1} Z_{it})$ is unobservable, it can be substituted by a consistent estimate based on a reduced-form probit model for the choice probabilities, and we can introduce the estimated $\hat{\lambda}_{it}$ in the Euler equation for capital in order to control for endogenous sample selection.

We proceed in three stages. We rst obtain consistent estimates of the selectivity correction terms λ_{it} by means of probit models for $D_{i,t+1}$ at each period. We then include the estimated $\hat{\lambda}_{it}$ in the Euler equation for capital, and we estimate the unrestricted parameters of the system of Euler equations for labour and capital, by GMM, using those observations with positive investment. The resulting estimates will be functions of the parameters of interest. In the third stage, we recover the structural parameters using a minimum distance estimator that exploits the constraints that the unrestricted parameters should satisfy.

Our approach allows us to separate two issues: the validity of instruments, and the restrictions that the unrestricted parameters of the Euler equations should satisfy as functions of the structural parameters. We can test the validity of instruments using a Hansen-Sargan test of the unrestricted GMM estimation, and the validity of the restrictions implied by the structural parameters can be tested using the minimum distance criterion. Alternatively, we could have also estimated directly the parameters of interest by restricted GMM. However, a rejection of the overidentifying restrictions in this context does not allow us to disentangle whether it is due either to invalid instruments or to the fact that the parameter restrictions are not ful lled by the data.

4 Estimation results

As we explained earlier, we control for sample selection using probit equations for positive investment. These equations were estimated year by year in order to allow for conditional heteroskedasticity.[1] We calculate the estimated $\hat{\lambda}_{it}$ for each observation with positive investment, and include it as an additional variable in the Euler equation for capital. The percentage of correct positive predictions is about 81 percent, and

[1] The resulting probit estimates will be provided upon request.

the pseudo-R^2 ranges from 0.23 to 0.27.[2]

The Euler equations for labour and capital are jointly estimated by iterated GMM (see Kocherlakota (1990) and Ferson and Foerster (1994) for a discussion of the finite sample advantages of iterated GMM vs. two-step GMM). We then recover the structural parameters using a minimum distance estimator. The results are presented in Table 3. Our instrument set includes lagged values of the rates of investment and hiring (arranged to enter as they do in the adjustment cost function), the logarithms of inputs interacted with their corresponding average productivities, and time and industry dummies.

Since one of our main concerns has to do with the flexibility of the adjustment cost specification, we first consider a restricted version of our model that ignores the adjustment cost interaction between labour and capital. In the first three columns of Table 3 we report the estimates of the Euler equations for these two inputs, assuming out adjustment cost interactions. Under such assumption, we can estimate separate equations for capital and labour; the results are shown in columns 1 and 2 respectively. These two columns show strong evidence of misspecification. First, in the basis of the Sargan tests, we reject the validity of the instruments, where the rejection is particularly strong in the case of labour. Second, we find an implausible value of the discount rate in the equation for labour, although its high standard error points out a potential identification problem. In column 3, we jointly estimate the two equations, and the results also indicate a strong rejection of the instruments.

In the last column, we present the minimum distance estimates of the Euler equations based on our more flexible specification for adjustment costs given by (13). We do not find evidence against this specification. The Sargan test does not reject the instrument set, and the minimum distance criterion does not reject the restrictions

[2] The pseudo-R^2 is defined as the relative gain in the likelihood function between the estimated model and a restricted model that includes only the constant term.

among the unrestricted parameters. We thus can conclude that the strong restrictions implied by the restricted adjustment cost function in the first three columns are behind the rejection of the former specification. Furthermore, the selectivity correction term is significant at the 10% level. We find an estimated discount rate slightly larger than one, but the lower bound of the 95% confidence interval is about 0.927, so that it includes plausible values of the discount rate.

Regarding the technological parameters, we find that the coefficients for the linear terms are significant and correctly signed, although the coefficient for capital seems to be very low. The medians of the sample distribution of the implied output elasticities are 0.47 for labour and 0.003 for capital, which appears to be implausibly small. On the other hand, neither the coefficients associated with the quadratic terms for labour and capital nor the interaction coefficient between them are significant. Finally, we find positive interactions with innovation, yet it is only significant for labour, and its size is not very large.

The adjustment cost parameters are significant, with the exception of b_{3L}, which is positive but non significant. Keeping capital stock constant, we cannot reject symmetry and convexity of adjustment costs for labour. This is consistent with Delgado and Jaumandreu (1998), who use nonparametric methods to estimate the shape of adjustment cost function for labour, and do not find evidence of non-convexities either.

Concerning capital, we find that adjustment costs are marginally increasing for reasonable levels of investment. However, we observe a certain evidence of non-convexity, although it appears for high values of the investment rates.

In addition, the interaction coefficient is positive and strongly significant, what is evidence of p-substitutability between labour and capital, in the sense that when adjusting one particular factor, the firm can reduce its marginal adjustment costs if it adjusts the other factor in the opposite direction.

We have obtained the sample distribution of adjustment costs relative to real output. For those firms that adjusted at least one input, we find a range between 0.04% and 18.4% for the percentiles 5 and 95, respectively, the median being about 1% of total output.

In order to give a more intuitive description of the estimated adjustment costs, we have evaluated adjustment costs for alternative reference values of the stocks of inputs. The reference values were selected in the following way. We divide the sample in four groups according to the quartiles of the sample distribution of the stock of fixed capital. Then, for each group, the reference values for capital and employment were set to their median values. In figure 1 we depict the shape of the adjustment cost function for these alternative values. Keeping the investment rate constant, we can see that asymmetries in adjustment costs for labour are only relevant for high values of the hiring rate, and we do not see evidence of non-convexities for labour adjustment. On the other hand, for a given hiring rate, we see evidence of non-convexities in adjustment cost for capital, particularly for high values of the investment rate.

5 Conclusions

In this paper we have examined the determinants of firms' labour and capital decisions under adjustment costs. For this purpose we have derived Euler equations for labour and capital in an intertemporal framework under rational expectations. One of the reasons why Euler equations for factor demands are often rejected in empirical studies, could be the lack of flexibility in the parameterization of the adjustment cost function. In this paper, we have used a flexible specification that allows for asymmetries and interactions in adjustment costs between labour and capital. In addition, we allow factor productivity to depend on innovation expenditure. We use a panel of

968 Spanish manufacturing companies along the period 1991-1995 for the empirical analysis.

Our results confirm that the usual assumption of adjustment cost separability between labour and capital is rejected by the data. The interaction term is positive and statistically significant, which implies p-substitutability between capital and labour. We do not find evidence against our more flexible specification for adjustment cost, and we get plausible estimates of the adjustment cost parameters. Our results imply non-convexities in the adjustment cost function for high values of the investment rate. However, we do not find evidence of asymmetry in the adjustment costs for labour. Finally, we find a reasonable value of the output elasticity with respect to labour, but the output elasticity with respect to capital seems to be too low. In addition, we find evidence of a positive effect of innovation on labour productivity.

The main weakness of our results has to do with the short data period available to estimate the model. Since our sample period does not cover a complete economic cycle, our parameter estimates could depend on the particular aggregate phenomena that dominated during the sample period. Furthermore, given that we have very few observations per firm, we cannot control for unobserved individual heterogeneity in estimation. A challenge for future research is thus to examine the adjustment cost structure using additional sample periods of data, in order to control for cyclical effects and for unobserved individual heterogeneity.

Data Appendix

The *Encuesta Sobre Estrategias Empresariales* (ESEE) is conducted by the Ministry of Industry and Energy. This database contains annual information for a large number of Spanish companies whose main activity was manufacturing between 1990 and 1995. The sample includes all companies with more than 200 workers and a representative sample of rms with less than 200 employees. In the second year of the survey (1991) the de nition of some variables changed and more information was collected. For this reason we have not considered 1990.

The sample consists on an unbalanced panel of 968 non-energy manufacturing rms which report full information in relevant variables for at least four consecutive years, from 1991 to 1995.

Table A1 presents the distribution of rms in the sample in 1993 by size and by 2-digits industry. The total number of employees at these rms is around 200,000, that represents approximately 9% of total Spanish manufacturing employment during this period.

Table A1
Distribution of rms by 2-digit industry and by size

		size					
		<=20	21-50	51-100	101-200	>200	*Total*
Iron, steel	Abs. freq.	4	3	3	1	11	22
and metal	% by ind.	18.18	13.64	13.64	4.55	50.00	100.00
(22)	% by size	1.45	1.41	4.00	1.01	3.61	2.27
Bldg. materials	Abs. freq.	19	20	5	10	19	73
glass, ceramics	% by ind.	26.03	27.40	6.85	13.70	26.03	100.00
(24)	% by size	6.88	9.39	6.67	10.10	6.23	7.54
Chemicals	Abs. freq.	18	15	2	6	39	80
	% by ind.	22.50	18.75	2.50	7.50	48.75	100.00
(25)	% by size	6.52	7.04	2.67	6.06	12.79	8.26
Non-ferrous	Abs. freq.	38	22	10	8	21	99
metal	% by ind.	38.38	22.22	10.10	8.08	21.21	100.00
(31)	% by size	13.77	10.33	13.33	8.08	6.89	10.23
Basic	Abs. freq.	15	14	4	7	15	55
machinery	% by ind.	27.27	25.45	7.27	12.73	27.27	100.00
(32)	% by size	5.43	6.57	5.33	7.07	4.92	5.68
Office	Abs. freq.	0	0	0	0	1	1
machinery	% by ind.	0.00	0.00	0.00	0.00	100.00	100.00
(33)	% by size	0.00	0.00	0.00	0.00	0.33	0.10
Electric	Abs. freq.	6	11	7	6	26	56
materials	% by ind.	10.71	19.64	12.50	10.71	46.43	100.00
(34)	% by size	2.17	5.16	9.33	6.06	8.52	5.79
Electronic	Abs. freq.	2	2	3	4	12	23
	% by ind.	8.70	8.70	13.04	17.39	52.17	100.00
(35)	% by size	0.72	0.94	4.00	4.04	3.93	2.38
Motor vehicles	Abs. freq.	1	1	4	10	29	45
	% by ind.	2.22	2.22	8.89	22.22	64.44	100.00
(36)	% by size	0.36	0.47	5.33	10.10	9.51	4.65
Ship	Abs. freq.	1	2	1	0	7	11
building	% by ind.	9.09	18.18	9.09	0.00	63.64	100.00
(37)	% by size	0.36	0.94	1.33	0.00	2.30	1.14
Other	Abs. freq.	0	0	1	1	3	5
motor vehicles	% by ind.	0.00	0.00	20.00	20.00	60.00	100.00
(38)	% by size	0.00	0.00	1.33	1.01	0.98	0.52
Precision	Abs. freq.	2	0	0	2	3	7
instruments	% by ind.	28.57	0.00	0.00	28.57	42.86	100.00
(39)	% by size	0.72	0.00	0.00	2.02	0.98	0.72

Table A1 (cont.)
Distribution of rms by 2-digit industry and by size

		size					
		<=20	21-50	51-100	101-200	>200	*Total*
Non-elaborated food (41)	Abs. freq.	31	23	9	7	33	103
	% by ind.	30.10	22.33	8.74	6.80	32.04	100.00
	% by size	11.23	10.80	12.00	7.07	10.82	10.64
Food, tobacco and drinks (42)	Abs. freq.	9	5	3	2	20	39
	% by ind.	23.08	12.82	7.69	5.13	51.28	100.00
	% by size	3.26	2.35	4.00	2.02	6.56	4.03
Basic Textile (43)	Abs. freq.	10	8	4	11	15	48
	% by ind.	20.83	16.67	8.33	22.92	31.25	100.00
	% by size	3.62	3.76	5.33	11.11	4.92	4.96
Leather (44)	Abs. freq.	7	3	0	1	1	12
	% by ind.	58.33	25.00	0.00	8.33	8.33	100.00
	% by size	2.54	1.41	0.00	1.01	0.33	1.24
Garment (45)	Abs. freq.	29	28	9	7	15	88
	% by ind.	32.95	31.82	10.23	7.95	17.05	100.00
	% by size	10.51	13.15	12.00	7.07	4.92	9.09
Wood and furniture (46)	Abs. freq.	31	24	1	2	4	62
	% by ind.	50.00	38.71	1.61	3.23	6.45	100.00
	% by size	11.23	11.27	1.33	2.02	1.31	6.40
Cellulose and paper edition (47)	Abs. freq.	26	15	3	5	13	62
	% by ind.	41.94	24.19	4.84	8.06	20.97	100.00
	% by size	9.42	7.04	4.00	5.05	4.26	6.40
Plastic materials (48)	Abs. freq.	18	10	4	9	12	53
	% by ind.	33.96	18.87	7.55	16.98	22.64	100.00
	% by size	6.52	4.69	5.33	9.09	3.93	5.48
Other non-basic (49)	Abs. freq.	9	7	2	0	6	24
	% by ind.	37.50	29.17	8.33	0.00	25.00	100.00
	% by size	3.26	3.29	2.67	0.00	1.97	2.48
Total	Abs. freq.	276	213	75	99	305	968
	% by ind.	28.51	22.00	7.75	10.23	31.51	100.00
	% by size	100.00	100.00	100.00	100.00	100.00	100.00

Construction of the stocks of R&D and xed capital

Market value of the stock of xed capital.

Since1991 the ESEE provides information on the book value and the average age of the stock of xed capital, and the year of the last regulation. It also includes data on gross nominal investment during the year. The market value of the capital stock (K_{it}) can be constructed using alternative years as reference. If we use year t as reference, we will calculate the market value of the stock of xed capital in year t as

$$K_{it} = (1 - \delta_i)^{age_{it}} KB_{it} \frac{q_t}{q_{m_i}}$$

where age_{it} is the average age of the capital stock of rm i in period t, δ_i is the depreciation rate, KB_{it} is the book value of the stock of xed capital, q_t is the price de ator of the stock of xed capital, and period m_i refers to the year of the last regulation in rm i. The price index is the GDP implicit de ator of investment goods constructed by the Spanish Statistics Office (INE) and is constant across rms. The depreciation rate is assumed to be constant over time and varies across sectors (source: Martín Marcos (1990)). For any other year, we calculate the market value of the stock of xed capital using a perpetual inventory method which takes account for depreciation and in ation

$$
\begin{aligned}
K_{is} &= (1-\delta_i)K_{is-1}\frac{q_s}{q_{s-1}} + I_{is} && \text{if } s > t \\
K_{is} &= \frac{(K_{is+1} - I_{is+1})}{(1-\delta_i)}\frac{q_s}{q_{s+1}} && \text{if } s < t
\end{aligned}
$$

The problem of this approach is that for $s < t$ we can get negative values and we have to set K_{is} to missing. We could have solved this problem using 1991 as reference for all the rms, however, for a certain number of rms, there is no enough information in 1991 to construct the market value of the stock of xed capital. Thus, for any rm we have calculated the market value of the stock of xed capital using different years as reference. Finally, the reference year was chosen to have the minimum number of missing values in the stock of xed capital.

R&D capital stock.

The ESEE data report information on total expenditure in R&D. We construct the R&D capital stock following Hall and Mairesse (1995) and we use a depreciation rate of 15% and a presample growth in real investment of 5%. Then, for each rm reporting positive expenditure in R&D for at least one year, we calculate the stock of R&D capital (KRD_{it}) for the rst year in which the expenditure in R&D is positive as

$$
KRD_{it} = \frac{RD_{it}}{0.05 + 0.15}
$$

where RD_{it} is the rm s investments in R&D at period t. For any other year, we compute the stock of R&D capital using a perpetual inventory method similarly as we did to construct the stock of xed capital. The price index we used is the GDP implicit de ator. We have also used different values for the depreciation rate and the presample growth in real investment. The results were very similar and will be provided upon request.

References

[1] Alonso-Borrego, C. (1998), Demand for labour inputs and adjustment costs: evidence from Spanish manufacturing rms , *Labour Economics* 5, 475-497.

[2] Bresson, G., F. Kramarz and P. Sevestre (1991), Labour demand and heterogeneous workers with non linear asymmetric adjustment costs , Mimeo (INSEE, W.P. No. 1924).

[3] Davis, S. and J. Haltiwanger (1992), Gross Job Creation, Gross Job Destruction, and Employment Reallocation , *Quarterly Journal of Economics* 107, 819-863.

[4] Delgado, M.A. and J. Jaumandreu (1998), Non-parametric estimation of adjustment cost curves of employment , Mimeo. (Fundación Empresa Pública, Madrid).

[5] Ferson,W.E..and S.R. Foerster (1994), Finite sample properties of the Generalized Method of Moments in tests of Conditional Asset Pricing Models , *Journal of Financial Economics* 36, 29-55.

[6] Hall, B.H. and J. Mairesse (1995), Exploring the relationship between R&D and productivity in French manufacturing rms , *Journal of Econometrics* 65, 263-293.

[7] Hamermesh, D. (1993), *Labor demand*, Princeton University Press, Princeton, NJ.

[8] Hamermesh, D.S. and G.A. Pfann (1996), Adjustment costs in factor demand , *Journal of Economic Literature* 34, 1264-1292.

[9] Kocherlakota, N. (1990), On tests on representative consumer asset pricing models , *Journal of Monetary Economics* 26, 285-304.

[10] Nadiri, I. and S. Rosen (1969), Interrelated factor demand functions , *American Economic Review* 59, 457-471.

[11] Martín Marcos, A. (1990), Estimación del stock de capital para los sectores de la Encuesta Industrial , Mimeo. (Fundación Empresa Pública, Madrid).

[12] Meghir, C., A. Ryan, and J. Van Reenen (1996), Job creation, technological innovation and adjustment costs: evidence from a panel of British rms , *Annales d Economie et de Statistique* 41/42, 255-274.

[13] Palm, F.C. and G.A. Pfann (1990), Interrelated demand rational expectations for two types of labour , *Oxford Bulletin of Economics and Statistics* 52, 45-68.

[14] Pindyck, R.S. and J.J. Rotemberg (1983), Dynamic factor demands under rational expectations , *Scandinavian Journal of Economics* 85, 223-238.

Table 1
R&D Investment by 2-digit industry
(reference year: 1993)

		Firms with positive R&D investment	
	R&D intensity	Absolute freq.	Percentage
Iron, steel and metal (22)	1.1	11	50.0
Bldg. materials (24)	0.7	19	26.0
Chemicals (25)	6.1	53	66.2
Non-ferrous metal (31)	1.0	31	31.3
Basic machinery (32)	3.0	35	63.6
Office machinery (33)	5.0	1	100.0
Electric materials (34)	6.9	36	64.3
Electronic (35)	16.2	21	91.3
Motor vehicles (36)	14.5	31	68.9
Ship building (37)	3.4	4	36.4
Other motor vehicles (38)	5.2	2	40.0
Precision instruments (39)	3.5	4	57.1
Non-elaborated food (41)	0.4	21	20.4
Food, tobacco & drinks (42)	0.4	14	35.9
Basic Textile (43)	0.9	17	35.4
Leather (44)	0.4	3	25.0
Garment (45)	1.5	19	21.6
Wood and furniture (46)	0.1	4	6.5
Cellulose and paper ed. (47)	0.4	9	14.5
Plastic materials (48)	1.6	20	37.7
Other non-basic (49)	1.5	9	37.5
Total	2.8	364	37.6

Note: R&D intensity is the percentage ratio of R&D investment to value added

Table 2
Descriptive Statistics (Weighted averages)

	Year			
	1992	*1993*	*1994*	*1995*
Gross job creation rate	1.86	1.46	3.79	2.70
Gross job destruction rate	6.61	8.77	4.89	3.40
Net job creation rate	-4.76	-7.31	-1.09	-0.69
Value added growth rate	-3.79	-5.35	13.77	5.02
Investment rate	15.27	11.11	9.76	15.23

Table 3
Estimation of Euler equations for
labour and physical capital

	(1)	(2)	(3)	(4)
Technological parameters				
α_K	0.0094 (0.0060)		0.0089 (0.0057)	0.0173 (0.0090)
α_{KK}	-0.0005 (0.0009)		-0.0006 (0.0009)	-0.0005 (0.0017)
α_{KL}	-0.0001 (0.0022)	-0.0566 (0.0171)	0.0002 (0.0021)	-0.0036 (0.0038)
α_{KR}	0.0000 (0.0005)		0.0000 (0.0005)	0.0013 (0.0011)
α_L		0.3697 (0.0731)	0.4498 (0.0682)	0.4794 (0.0704)
α_{LL}		0.0448 (0.0125)	-0.0033 (0.0060)	-0.0030 (0.0061)
α_{LR}		0.0093 (0.0066)	0.0129 (0.0063)	0.0144 (0.0065)
Adjustment cost parameters				
b_{2K}	0.6149 (0.1377)		0.5908 (0.1308)	0.5722 (0.1795)
b_{3K}	-0.5262 (0.1391)		-0.4958 (0.1312)	-0.5050 (0.1806)
b_{KL}				0.4593 (0.1114)
b_{2L}		0.1430 (2.0200)	6.6746 (1.6868)	7.5218 (1.6448)
b_{3L}		-0.1717 (2.4348)	3.9366 (5.3037)	1.8115 (5.6024)
Discount rate	1.0367 (0.0533)	47.2541 (663.6467)	1.0452 (0.0508)	1.0477 (0.0617)
Selectivity term	-0.0625 (0.0272)		-0.0612 (0.0255)	-0.0603 (0.0370)
Sargan test (df)	28.94 (17)	49.46 (19)	71.65 (36)	41.21 (32)
p-value	0.0351	0.0002	0.0004	0.1276
Q test (df)	8.59 (2)	2.90 (1)	13.80 (5)	12.22 (8)
p-value	0.0136	0.0887	0.0169	0.1418

Figure 1: Adjustment Costs