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Evidence from Norwegian Manufacturing Plants 1982-92

Discussion Papers No. 159 • Statistics Norway, December 1995

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Abstract:
It is often claimed that the opportunities to create new manufacturing jobs in open, high-cost economies such as Norway, are concentrated in products which are technologically advanced and knowledge intensive. This paper examines the relationship between job creation and innovation, as measured by R&D investments, in Norwegian manufacturing. We compare job creation in plants belonging to R&D firms to plants belonging to firms without R&D. We also compare job creation in plants belonging to high and low tech industries. Our data set covers more than 80 percent of manufacturing employment in Norway over the period 1982-92. The paper challenges the optimistic view about job creation in R&D intensive firms and high-tech industries. Some main findings are: (i) Net job creation is not higher in high-tech industries. (ii) There is no clear-cut positive relationship between net job creation and the R&D-intensity of the firm. (iii) There is less net job creation and less job-security in R&D-intensive firms in the late 1980s and early 1990s.

Keywords: R&D, innovation, job creation, job destruction.

JEL classification: E32, J23, J63, O32, O33.

Acknowledgement: Paper presented at the conference "Technology Adoption and Skill Levels, Wages, and Employment", in Washington, April 30, May 1-2, 1995, and at the IFS Conference on "R&D, Innovation and Productivity" in London, May 15-16, 1995. We have benefited from comments at these conferences and at a workshop organized by NUPI, and from suggestions from Rolf Aaberge, Einar Bowitz, Ådne Cappelen, John Dagsvik, Erling Holmøy, Frode Johansen, and Knut Moum. The remaining errors are our responsibility. This project has received financial support from the Norwegian Research Council (Nærings-LOS).

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1 Introduction

It is often claimed that the opportunities to create new manufacturing jobs in open, high-cost economies such as Norway, are concentrated in products which are technologically advanced and knowledge intensive. There are clearly a number of successful R&D intensive firms in Norway, but the record is mixed; there are also some striking failures e.g. in the Norwegian electronics industry during the last 5 to 10 years[1]. This paper goes beyond individual case studies, and examines the relationship between job creation and innovation (measured by R&D investments) on a broader basis. We compare the rate of job creation in plants which belong to R&D firms on the one hand and no-R&D firms on the other. We also compare the patterns of job creation in plants belonging to industries with different R&D-intensities. Our data set covers more than 80 percent of manufacturing employment. As we show, the results question the optimistic view about job creation in R&D intensive firms and high-tech industries.

The analysis of the relationship between innovation and job creation - or job destruction - is a very old topic in economics, with Ricardo's chapter "On machinery" as the classical contribution (Ricardo, 1817). This relationship has regained interest recently with the more and more widespread use of automation based on information technology[2]. As emphasized by Katsoulacos (1984, 1986) and others, it is important to distinguish between micro and macro employment effects of innovation, or between the employment effects of the innovation for the innovating firm versus the firms which uses the goods which embody the innovation. This study focuses on the employment effects of innovation for the innovating firms, while neglecting the wider consequences. More precisely, we examine the direct relationship between job creation and the investment activity in innovation measured in terms of R&D expenditures. This narrow focus is not uninteresting as a considerable amount of governmental subsidies is aimed at boosting (private and public) R&D investment with job creation as one primary objective[3]. Clearly, the relationship between innovation and job creation can be entirely different in the industries *using* the innovations (e.g. banking or telecommunication) and those building on the innovations by producing complementary products (e.g. software production). However, these wider repercussions are outside the scope of this study.

Our paper is also concerned with a second topic; the job stability or job security in high tech

[1] Cf. Norsk Data and Kongsberg Våpenfabrikk.

[2] See European Commission (1994) for a policy oriented discussion of the issue. See OECD (1995) for different viewpoints. Berman et al. (1993) has examined the relationship between new technology and labor demand in an econometric study for US manufacturing.

[3] See e.g. St.meld. nr.36, (1992, pg. 3): "Research and development and the utilization of new knowledge are the most import means to obtain a high level of employment and a high standard of living" (our translation).

firms and high tech industries. In the policy debate, focus is often concerned not only with the number of jobs, but also with the quality of the jobs e.g. in terms of job security. In the academic literature, the issue of turbulence and persistency of firms in innovative industries has also been a focus of analysis and debate. Schumpeter (1943) introduced the term *creative destruction* as particularly important for industries characterized by large innovative opportunities and the perpetual introduction of new and better products. His view was that innovative industries would be particularly turbulent, as the race for rents associated with new products would create a process where one dominating firm is replaced by another firm raised by a new entrepreneur, and so fourth. During the 1980s, the question of innovation, pre-emption and the persistence of monopoly was examined extensively in the game theoretic literature[4]. As is often the case in theoretical models of industrial organization, there is no clear cut prediction emerging from these models; the outcome depends on the order of moves etc. In the empirical literature, the stability of R&D patterns and innovative dominance as measured by patents, are well documented; see Griliches et al. (1986). Klette (1995) has suggested that knowledge accumulation might involve some positive feedback which will create *persistent dominance* among innovative firms. The empirical approach we use below is quite well suited to illuminate whether R&D-intensive firms (industries) are characterized by more or less turbulence of jobs than other firms (industries).

The paper is outlined as follows: The next section presents our data sources and the definitions of concepts such as job creation etc. Section 3 gives an overview of the relationship between net job creation and job turnover in plants belonging to high vs. low tech industries. We also compare plants in firms which invest at different levels in R&D. As we show in this section, there are some interesting changes in the patterns of job creation over the period 1982-92. We show that during the slump in the late 1980s, there is a surge of job destruction which hits the R&D plants particularly hard. We examine whether this pattern is dominated by a few large plant closures, or whether there is a more general tendency affecting a large number of R&D plants. In section 4 we compare job creation in R&D and no-R&D plants in different industries. One of the questions we address is: To what extent does job creation take place in no-R&D plants belonging to an R&D-intensive industry? In section 5, we examine the relationship between R&D and job creation by means of a number of regressions. The motivation is two-fold: First, we want to examine whether the differences we present graphically in the previous sections are statistically significant. This allows us to account for the importance of heterogeneity within the group of R&D and no-R&D plants. Second, the regression framework allows us to simultaneously control

[4]See Reinganum (1989, section 3) for a survey, and Ericson and Pakes (1995) for a recent contribution to the literature.

for a number of variables, viz. industry and year specific shocks, size effects and exposure to foreign competition. Finally, we provide our conclusions and discuss some implications of our findings in section 6.

2 Data and definitions

2.1 Definition of job creation

It is by now well established in the literature to relate the amount of (gross) job creation and (gross) job destruction to the difference in employment in plants between two periods. *Job creation* is the difference in employment in all plants that increase employment between the two time periods, while *job destruction* is the corresponding number for all plants that reduce their employment. *Net job creation* is the difference between job creation and job destruction. *Gross job reallocation* – also termed *total job-turnover* in the literature[5] – is the sum of job creation and job destruction. Gross job reallocation includes both movements of jobs between plants and net changes in the number of jobs. All the concepts defined here (job creation, job destruction, net job creation and gross job reallocation) can be defined at the industry level or at the aggregate level. Appendix A presents formal definitions of job creation and related concepts.

Our measures of job creation and job destruction do not include the reallocation of jobs *within* plants, since our measures are constructed by adding up the *net* plant-level employment changes. Neither will our job creation measure capture new jobs that are left unfilled, i.e. new jobs that create vacancies. On the other hand, a vacancy that is filled will *cet.par.* be counted as a contribution to our measure of job creation, also if the job/vacancy have existed for some time.

One might argue that it would have been better to use the firm rather than the plant as the unit of observation in our analysis. We will discuss this point in the concluding section.

2.2 The data sources

A. The data on manufacturing plants

Our primary data source is the annual census of the Norwegian manufacturing sector covering the period from 1982 to 1992[6]. This census covers, in principle, all manufacturing plants except units where the owner is the only person employed. Consequently, there is no serious question

[5]Notice the distinction between *worker* turnover rates and *job* turnover rates; see e.g. Davis and Haltiwanger (1992) for a discussion of their relationship. Unfortunately, it is not possible to compare the job turnover rates presented in this paper with worker turnover rates, as worker turnover rates are not available for Norway.

[6]See Statistics Norway (several years), *Manufacturing Statistics*, Official Statistics of Norway NOS C 36, Statistics Norway, (Oslo), and Halvorsen et al. (1989) for details on the construction of these data sets.

about representativeness and sampling errors in this data set, as long as the manufacturing sector is the sector of interest[7]. The unit of observation is the plant. *Employment* is defined as the *annual average* number of people employed, including part-time workers and owners. Each plant is identified by a number which remains unchanged until production ceases to take place at the cite. Ownership changes do not affect the identification number; only the company code associated with the plant will be altered when there is a change in ownership. This system is useful when we want to account for the importance of plant turnover on job creation and destruction in a correct way. Other studies in the job creation literature have been plagued by excessive counts of entries and exits, and thereby exaggerating the amount of job creation and the importance of plant turnover for gross job reallocation, as they have not been able to separate ownership changes from real plant turnovers.

B. The R&D data and the merged data set

The R&D data have been taken from the Norwegian R&D surveys in 1983, 84, 85, 87 and 1989, carried out by The Norwegian Research Council for Science and Technology (NTNF)[8]. We have also used the R&D survey carried out by Statistics Norway in 1991. These surveys are essentially censuses for all firms with more than 20 employees in the R&D intensive, manufacturing industries. For firms with less than 20 employees, the coverage is less comprehensive. Consequently, we have eliminated from our sample firms with average employment[9] less than 20 employees. The R&D data have been merged (manually) with the plant data, using company names and addresses.

One attractive aspect of this data source is that the file reports R&D disaggregated by 'line of business' *within each firm*. Although the majority of firms report R&D in only one 'line of business' such a breakdown by 'line of business' is informative for firms that produce in several 'lines of business', as this breakdown helps us to identify the target 'line of business' for the R&D activity[10].

In the rest of this paper we will refer to *R&D plants*, defined as plants which belong to a firm which have reported R&D activities within the plant's (3-digit ISIC) line of business, at least once during the period 1983-91. This is clearly a quite broad definition, so we have also distinguish between high- and low-R&D plants in parts of our analysis. A high-R&D plant

[7] This statement is perhaps overly optimistic, as misreporting of the employment level in individual plants could be a significant source of error in our analysis.

[8] See Naas (1993) for an analysis of the pattern in the aggregate data across industries and the years 1985-89.

[9] The average is taken over the years when the firm is operating.

[10] Economies of scope in R&D suggests that we could define the R&D plants on the basis of the firm's R&D activity irrespective of 'line of business'. See Klette (1995) for an analysis of economies of scope in R&D.

belongs to a line of business within a firm which has a ratio between R&D-expenditure and sales above 1 percent in at least two years. This definition divided the set of R&D-plants into two almost equally large groups. We have chosen a wide definition of R&D-plants since the coverage of small and young firms is somewhat incomplete in the R&D surveys. Experiments with different definitions of R&D-plants revealed that our results are quite robust to changes in these definitions.

Table 1 reports some summary statistics[11]. Almost all industries have reduced the number of jobs over the period 1982-92 [12]. The reduction in the number of jobs is larger for the R&D plants than for the no-R&D plants. This claim is true both in relative and absolute terms.

3 An overall view

3.1 Job creation in high and low tech *industries*

Do industries with a high R&D intensity create more jobs than others? Figure 1 presents the average R&D intensity, defined as R&D-investment per value added, for the industry and the industry's average annual net job creation rate over the period 1982-92. The numbers in this plot refer to the industry codes listed in table 1 and appendix B. The figure reveals no significant positive relationship between net job creation and R&D-intensity across industries. The slope from the OLS-regression is 0.49, with a standard error of 0.87[13]. Indeed, plants in the most R&D intensive industry, electronics (industry code: 12), are clearly below average in terms on net job creation. As one can see from the figure, there is a stronger positive relationship between R&D-intensity and net job creation if one disregards the electronics industry.

Figure 2 shows the relationship between the average annual job reallocation rate and the average R&D intensity for the industry. The figure reveals a positive, but insignificant relationship between these two variables: The slope coefficient of an OLS-regression is 1.01, with a standard error of 1.17[14]. Across industries, there is no significant relationship between the R&D activity and the rate of job reallocation.

In figure 3, we have divided the whole manufacturing sector into three industry groups according to OECDs definitions of high, medium and low tech industries (see appendix B for

[11] The differences in manufacturing employment (e.g in 1987) in our sample compared to the numbers reported in the Manufacturing Statistics (several years) from Statistics Norway are due to our limited sample which disregards plants belonging to firms with average employment less than 20.

[12] The two industries with growth in the number of jobs, "Scientific instruments" and "Other manufacturing", are the two smallest industries we consider (in terms of 1987 employment).

[13] The weighted OLS-regression, with industry employment in 1987 as weights, gives an estimate of the slope equal to -0.38, with standard error 0.62 .

[14] We obtained an estimate for the slope equal to 2.45, with standard error 1.41, in the weighted OLS-regression with industry employment in 1987 as weights.

details). Figure 3.a (in the upper left hand corner) shows the job creation rates for the three industry groups. In the years 1984-89, job creation is highest in the high-tech industries, while the job creation rates are lowest in the low tech industries in all years except 1990. The next graph - figure 3.b - (in the upper, right hand corner) shows that the job destruction rate for the high tech industries vary substantially over the period: In the early 80s, the job destruction rates are low, while they increase in the second half of the 1980s and stabilize at a quite high level at the end of the period we consider. Consequently, the net job creation rates for the high tech industries start out relatively high in the early 80s, but then drop dramatically from 1987/88 onwards; see figure 3.c . From 1988 onwards, net job creation is lowest in the high tech industries. Figure 3.d shows that job reallocation is highest in the high tech industries from 1987 onwards.

We should point out that the graphs presented in figures 3-5 in this paper are all 3 year moving averages[15]. This brings out the trends in the data more clearly.

These large changes in job creation for some of the manufacturing sectors can be related to macroeconomic changes. During the period 1982-92, the Norwegian economy was characterized by a boom in 1985 and 1986, and a recession in 1983 and from 1988 onwards. The Norwegian economy was severely affected by the decline of the oil price in 1986. A serious crisis also hit the banking sector a few years later[16]. The slump at the end of the 1980s created slow wage growth and gains in competitiveness from 1989 onwards; see appendix C for a brief discussion of changes in competitiveness for Norwegian manufacturing 1982-92.

3.2 Job creation in high and low tech *firms*

The large amount of heterogeneity within (narrow) manufacturing sectors e.g. in terms of R&D-investment, is one of the striking facts emerging from studies of firm level data[17]. In particular, even in the most R&D-intensive industry - "Electronic equipments" (ISIC 383) - a large fraction of the plants do not report any R&D over the whole 11 year period we consider. On the other hand, in a low tech industry (according to the OECD classification) such as shipbuilding, there are well known Norwegian firms which have specialized in knowledge-intensive niches of the market producing e.g. high-speed ferries. We will now shift the focus away from differences between industries, and compare plants belonging to R&D firms to plants belonging to firms doing (reporting) no-R&D, without consideration of the characteristics of the industry they belong to.

[15] I.e. the estimate for 1984 is based on the observations in 1983, 84 and 85.
[16] See Steigum (1992) for a discussion of the Norwegian banking crisis.
[17] See Klette and Johansen (1995).

A. A first look

Before we examine the differences between R&D and no-R&D plants, consider the total job creation rate for all manufacturing plants, as indicated by the unbroken line in fig. 4a. The job creation rate in figure 4.a is remarkably stable over the whole period, despite the significant changes in the business cycle conditions. Turning to the job destruction rates in figure 4.b, there are some pronounced changes. The cyclical pattern of the job destruction rate and the stability of the job creation rate has been noticed before for the Norwegian economy and other economies; See Klette and Mathiassen (1995) and in particular Salvanes (1995) for an analysis of the cyclical patterns of job creation in the Norwegian economy.

Let us now return to the main point - the differences between R&D and no-R&D plants. Figure 4.a shows that the no-R&D plants have higher job creation rates in all years, and the difference between the R&D and the no-R&D plants is very stable. There was a convergence in the job destruction rates for R&D and no-R&D plants over the period 1982-92 (figure 4.b). While the net job creation rate was higher in R&D plants in the first half of the 1980s, this changed from 1986 onwards, when net job creation was higher for the no-R&D plants (figure 4.c). The reallocation rate is higher in the group of no-R&D plants, although there is some tendency to convergence (figure 4.d).

The differences in the *levels* of job creation, job destruction and job reallocation partly reflects the fact that R&D plants tend to be larger than no-R&D plants (cf. table 1). A number of studies have documented higher rates of job creation, job destruction and job reallocation for smaller plants; see e.g. Klette and Mathiassen (1995) and Davis, Haltiwanger and Schuh (1994). However, the difference in terms of *net* job creation between large and small plants varies between countries; Klette and Mathiassen (1995) found higher net job creation in small Norwegian manufacturing plants while Davis, Haltiwanger and Schuh (1994) did not find any relationship between plant size and net job creation in US manufacturing.

B. Comparing plants with different R&D intensities

As noted above, our definition of R&D plants is very broad, and a number of the R&D plants belong to firms which do (report) very little R&D over the period we consider. In figures 5.a-5.d, we present separate graphs for high-R&D and low-R&D plants, as defined in section 2.2. Figures 5.b shows that the high-R&D plants experienced a dramatic increase in the job destruction rate in the late 1980s. Notice that there is only a small drop in the job creation rate in 1988, and job creation is rising in 1989 when the job destruction rate was at its peak level.

As shown in figure 5.d, the job reallocation rate for high-R&D plants almost doubled from 1983 to the peak in 1989, while their net job creation rate plunged in the late 1980s. In the early 90s, the high-R&D plants partly recovered in terms of net job creation, with a net job creation rate similar to the low-R&D plants in 1992, but somewhat below the plants without R&D. The job destruction rate declined for both high-R&D and no-R&D plants in the early 1990s.

C. Tendencies or a few disasters?

Some of the declining firms in the electronics industry - the industry with the highest R&D intensity - received much attention in the late 1980s (in particular Norsk Data and Kongsberg Våpenfabrikk). However, our results presented in figure 6 support the view that the poor performance of the R&D intensive plants in terms of net job creation are not (entirely) due to these few cases, but rather a more general tendency in a large number of plants.

In figure 6, we have presented the log of employment for each plant, as a function of different ranks[18]. That is to say, the graph in the upper left corner, shows log employment in 1983 for each plant as a function of the rank of the plant in terms of employment in 1983. The next graph to the right shows log employment in 1986 as a function of the rank order in 1983. The dots show the individual observations, while the continuous graph shows a smoothed local average. For comparison, we have also plotted the original line from the previous graph. Notice that the dots at the bottom of each graph represent plants which are closed down. The next graph to the right reveals the same information, but for 1989, while the last graph in the first row refers to 1992. The next line of graphs is similar, but with 1986 rather than 1983 as the point of departure. The third line starts with 1989, while the graph in the right lower right corner represents 1992. The graphs in figure 6 show only the high-R&D plants.

Consider the first line of graphs in figure 6. The first thing to notice is that the decline in employment from 1986 to 1989 is reflected in almost all size classes. This can be seen from the fact that the curve which captures the local average is below the original curve for all size classes. Clearly, the graphs show that the decline in employment in the R&D-intensive plants is not only a decline in a few plants, but a more general tendency. The graphs suggest that the percentage decline in employment is similar for large and small plants as the distance between the curves is roughly constant (above some low level)[19]. Not too much emphasis should be put on this point since the picture is influenced by our treatment of plants which are closed down.

[18] These plots were inspired by Quah's (1994) so-called "cross-profiles".

[19] Notice that since we have *log of employment* on the vertical axis, the distance between the two curves in the graph is proportional to the *relative* decline in output. That is, a larger distance represent a larger *percentage* decline in employment.

We have arbitrarily set their employment equal to the employment in the smallest plant in 1983.

The graphs show that despite the general tendency of decline in employment from 1986 to 1989, there are a number of small plants which have expanded substantially (see e.g. the dots on the left hand side of the graph for 1989 in the first row). But there is also a large number of small plants which have failed, so the average experience among small plants is also a decline in employment. The large dispersion in growth rates for small plants (and firms) have been examined by Klette and Mathiassen (1995).

The graphs on the diagonal show that there is little tendency towards a more homogeneous size distribution of plants.

4 Industry differences in the relative performance of R&D firms

In the previous section we focused on the rate of job creation in R&D-intensive plants relative to other manufacturing plants, without considerations of the industries to which the plants belong. In this section we will consider the rate of net job creation in R&D plants relative to no-R&D plants *within the same industry*. Figure 7 shows the net job creation rate for R&D vs. no-R&D plants for different industries. The three graphs correspond to the periods 1982-86, 1987-89 and 1990-92. Notice that observations above the diagonal line in each graph indicate a higher net job creation for the R&D-plants relative to the no-R&D plants within the same industry.

In the first period, 1982-86, the observations are scattered quite symmetrically around the diagonal line, suggesting that there is little systematic difference in net job creation between R&D- and no-R&D plants within the same industry. There is little systematic change when we consider the second period 1987-89. However, we notice that two industries have moved significantly. The no-R&D plants are performing well *in relative terms* in the most R&D-intensive industry "ISIC 383: Electrical apparatus" (cf. industry 12). On the other hand, the situation is the opposite in one of the other R&D-intensive industries "ISIC 350-352 - Industrial Chemicals" (cf. industry 5). In the last period, 1990-92, there is a general movement of the observations downwards to the right. That is, the performance of the R&D-plants is deteriorating in *relative* terms. But the general movement of the observations to the right correspond to higher net job creation in no-R&D plants.

To summarize, if we consider net job creation in R&D-plants compared to other plants in the same industry, there is a downward trend across the three subsequent periods we consider in figure 7. While net job creation improves somewhat in the early 90s for the no-R&D plants, there is little similar improvement for the R&D plants.

One should be careful not to draw too strong conclusions from this analysis. In particular, this analysis is a pure descriptive investigation and does *not* provide a ready answer to the counterfactual question: What would happen if the R&D plants stopped their R&D activity? One might even suspect that job creation in the no-R&D plants in the high tech industries would deteriorate if they could not benefit from the R&D effort of the R&D firms, as knowledge spillovers are widely believed to be important in high tech industries. However, econometric estimation of the magnitude and directions of knowledge spillovers remain unsettled research topics and is outside the scope of this paper – see Klette (1994, 1995) for some evidence from Norway and Griliches (1992, 1995) for surveys of the literature.

5 A regression analysis

So far, the comparisons has been based on graphical displays, and one might wonder whether the differences we have pointed out between R&D and no-R&D plants are large relative to the variation within each group of plants. Are the differences in the *average* rates of job creation between the two groups of plants capturing a significant difference, or is there so much heterogeneity among, say, the R&D-plants that the differences between the averages are insignificant relative to the variation within the groups? To examine this question, we will next present a regression analysis which has the additional benefit that it allows us to simultaneously control for several variables, such as year, industry and size differences. As shown in Klette and Mathiassen (1995), large plants have reduced their employment more than smaller plants, and we also know that the fraction of plants doing R&D increases with size. It is therefore of some interest to see whether this is the essential "explanation" for the patterns with less job creation in R&D-plants.

5.1 Econometric issues

Before we present the econometric model and results, we have to consider some econometric issues. We want to relate the (net) job creation rates at the plant level, θ_{it}, to a number of plant characteristics within an econometric framework, i.e. we want to establish a formal model where θ_{it} is assumed to depend on a set of covariates, X_{it}, such as industry wide shocks and firm sizes, in addition to a dummy variable for whether the plant belongs to an R&D firm or not. The (net) job creation rates for each firm is defined analogously to the net job creation rate for a sector (cf. appendix A), i.e. $\theta_{it} \equiv (N_{it} - N_{i,t-1})/[(N_{it} + N_{i,t-1})/2]$. These growth rates are well defined also for plant exits and births, where they take on the values -2 and 2, respectively.

In order to account for the limited range of variation for θ_{it}, we have borrowed an idea from models for limited dependent variables. Define

$$\tilde{\theta}_{it} = \ln\left(\frac{c+\theta_{it}}{c-\theta_{it}}\right), \tag{1}$$

where c is some number larger than 2. We have arbitrarily chosen $c = 4$, but also experimented with lower values.

The most general model we have considered can be more explicitly stated as

$$\tilde{\theta}_{it} = \lambda_{It} + \lambda^{s}_{it} + \beta_l D^{LR}_{it} + \beta_h D^{HR}_{it} + e_{it}. \tag{2}$$

Here λ_{It} and λ^{s}_{it} are industry times year dummies and size dummies. There are three size classes. In order to avoid a "regression-to-the-mean-bias" (see Davis, Haltiwanger and Schuh, 1994 and Friedman, 1992), we have classified the plants into size groups according to average (in periods t and t-1), rather than initial size. We classify the plants according to the size of the whole mother firm.

R&D is captured by dummy variables. This is done in order to follow the graphical analysis in the previous sections as closely as possible. D^{LR}_{it} and D^{HR}_{it} are dummies that define whether the firm's R&D investment is low (L) or high (H). If the firm is not investing in R&D, both dummies will be zero. We have considered two alternative sets of results; one set as described above and another set where we do not distinguish between high- and low-R&D plants. In the last case only one β parameter is estimated.

The model in equation (2) is only a descriptive framework and not a model with a structural content.

For each of the two specifications, we have estimated four different regressions, which include the different control variables in addition to the R&D-dummies. Specifically, we present the regressions 1-4:

1. This regression imposes the constraint that $\lambda_{It} = \lambda_t$, and $\lambda^{s}_{it} = 0$. That is, the model contains only year dummies. This regression examines whether R&D-plants create more jobs than no-R&D plants without controlling for industry differences.

2. Here $\lambda^{s}_{it} = 0$, while we allow for a full set of interaction between year and industry dummies. This regression consider whether R&D-plants create more jobs than no-R&D plants when we control for industry differences and let these differences vary across years.

3. This is the regression equation in (2), which also controls for differences in job creation between firms of different sizes.

4. The last model is the same as the previous model, but with industry dummies replaced by dummies for three different manufacturing sectors according to their exposure of foreign competition; export oriented, import competing or sheltered.

All models have been estimated by weighted OLS regressions, with annual shares of employment as weights. Our motivation for using weights is once more to follow the graphical analysis in the previous sections as closely as possible. Notice that the net job creation rate in a sector is $\theta_t^{NJC} = \sum_i w_{it}\theta_{it}$, where w_{it} is the share of employment in plant i. Our weighted regressions should therefore give estimates of the coefficients comparable to the graphs, which (implicitly) also weight the plant specific job creation rates by employment shares.

5.2 Empirical results

In the first set of estimates, presented in table 2, we have pooled all R&D-plants into one group, and considered the question whether these plants differ from other plants. The table presents only the estimates for the coefficient for the R&D-dummy together with the heteroskedasticity consistent standard errors in parentheses. In the first column, only time dummies are included in addition to the R&D-dummy. The R&D-coefficient changes from (insignificantly) positive for the first period to significantly negative for the last period. This confirms the pictures we have presented above; the main additional information from this regression is that the difference between R&D and no-R&D plants in the last period (1990-92) is 'large' relative to the variation across plants within each group, since the R&D parameter is highly statistically significant. That is to say, the differences in (weighted) averages presented e.g. in figure 4 are not misleading; the difference in the net job creation rates presented in figure 4 are not negligible compared to the large amount of heterogeneity among the different groups of plants not revealed in the figure.

The next column is based on a regression which includes industry specific time dummies. The pattern is very similar to the results presented in the previous column, with a declining relative rate of job creation for the R&D plants. That is, if we by means of a regression control for industry differences in job creation patterns, we still find that the R&D plants are creating less jobs than the no-R&D plants. This finding supports the conclusion we draw from figure 7, discussed in section 4.

In column 3, we have augmented the model in column 2 by adding three dummies for size classes, corresponding to plant employments in the intervals: (i) ≤ 50, (ii) 51-200, and (iii)

200+. The estimates show that the relative performance of R&D plants is essentially the same if we restrict the comparison to firms of the same size within the same industry and year.

In the last column, we examine whether the result is altered if we compare plants within groups defined according to different classes of foreign competition. It is natural to consider whether our results are affected by differences in foreign competition between the R&D and the no-R&D plants. For example, the poor performance of R&D plants could reflect that these plants are more export oriented, and that the Norwegian competitiveness has suffered in the period we consider. The results in column 4 suggest that the deteriorating performance of R&D plants is not changed if we compare the plants according to whether they are export oriented, import competing or sheltered. One might still argue that within these industries, the R&D plants are larger - or belong to larger firms - which tend to be more export oriented and exposed to foreign competition. Recall, as pointed out in section 3.1 (and explained in more detail in appendix C), that most indices of competitiveness deteriorated in the *early and mid 80s*, and, if anything, improved in the late 80s and early 1990s. Hence, the timing is not favorable to the view that a deteriorating competitive position for Norwegian manufacturing can explain low net job creation for the R&D plants.

Table 3 distinguishes between high- and low-R&D plants, as defined in section 2. The magnitude of the coefficients largely supports the graphs presented in section 3. From the first (1982-86) to the last period (1990-92), the relative rate of job creation for the high-R&D plants declines even more than for the low-R&D plants.

6 Conclusions

This study suggests that there is no clear-cut positive relationship between R&D and net job creation. Considering Norwegian manufacturing plants over the period 1982-92, we find that both at the industry and the plant level, the most R&D-intensive units have declined in terms of jobs (i.e. employment) relative to the rest of the manufacturing sector. High tech industries[20] and high R&D plants did quite well in terms of net job creation in the early 1980s, while they eliminated a number of jobs in the late 80s and early 90s. The low net job creation rates for R&D plants emerge even if we restrict the comparison to other plants in the same industry, also in the high-tech industries. Tightening the comparison group even further by controlling for plant size does not alter this picture. However, we have emphasized that this is a purely descriptive analysis which does not predict the outcome of a counterfactual situation where

[20] as defined by OECD, cf. appendix B.

e.g. the R&D firms stopped their R&D-investments. As pointed out above, the importance of spillovers in knowledge accumulation might cause the performance even for the no-R&D plants to deteriorate if such an event should take place.

It has been argued that the evidence from Norway might be exceptional as Norway has large oil revenues which has deteriorated manufacturing competitiveness. We believe that this claim is less than obvious for at least two reasons. First, the timing seems problematic. The competitiveness for Norwegian manufacturing deteriorated in the period 1982-87, when the R&D plants did quite well in terms of net job creation. Competitiveness, if anything, improved at the end of the 1980s when job destruction was most pronounced for the R&D plants. Nevertheless, it would clearly be interesting to look at the evidence for other countries as well. The performance of e.g. the computer industry in the US - with leading companies such as IBM and DEC eliminating a large number of jobs - hints that the Norwegian evidence might not be exceptional.

Second, and perhaps more important, it is exactly because Norway is such a high cost country - not least due to the oil revenues - that innovation is regarded as a mean to preserve competitiveness. It can be argued that it is exactly in a country like Norway, in a period when international competition has been widened and more fierce, that one would expect *a priori* that the arguments for the importance of innovation to preserve competitiveness should be most valid.

Our study has revealed that there is no systematic tendency for higher job security in high-tech industries or plants. As we go through the period 1982-92, the patterns change substantially. In the early and mid 80s, job reallocation was lower among the R&D plants, but the picture changed during the late 80s and early 90s when job destruction took place in the R&D-plants. Interestingly, for the high tech industries, and among the high-R&D plants, job creation was high at the same time as job destruction was at its highest. This suggests that a restructuring and not only a reduction took place among these plants.

One might argue that it would be interesting to use the firm rather than the plant as the unit of observation. Using the firm rather than the plant would hide reallocation of jobs between plants within a single firm. As the R&D plants more often tend to belong to multi plant firms, shifting to firms as the unit of observation would tend to reduce both the job creation and the job destruction rate, thereby reducing the job reallocation rate while not affecting the net job creation rate. On the other hand, a significant number of the R&D firms went through corporate restructurings in the period we consider. This would work in the opposite direction, by *cet.par.* increasing both the job creation and the job destruction rates when we compare the rate for the R&D-*plants* to the rate for the corresponding R&D-*firms*. Hence, it is not clear which way the picture would change in terms of job creation, job destruction and job reallocation. But, in terms of *net* job creation we know that the picture would remain the same.

Finally, we want to emphasize that job creation is far from the only interesting performance indicator for R&D firms and high tech industries. Almost all the studies on R&D and performance that use firm-level data, have focused on the relationship between R&D, value added and productivity, and paid little attention to job creation[21]. One primary objective of innovation is to increase value added *per unit of input* (including workers). Hence, a successful strategy in terms of increased value added per unit of input (or, per worker) could show up in a "poor" performance in terms of job creation. Indeed, this seems to be exactly the picture we find for Norwegian manufacturing over the period we consider. A complementary paper by Klette and Johansen (1995) considers performance in terms productivity and profits using the same data set as in the present study. One of the findings in that paper is that the "poor" performance in terms of job creation for the R&D plants identified in the present paper, does not carry over when we consider performance in terms of productivity and profits. In Klette and Johansen (1995) preliminary results suggest that the positive relationship between R&D and productivity is stronger in the late 80s and early 90s than in the early and mid 80s.

[21] See Griliches (1994, 1995) for surveys of this literature. Klette (1994, 1995) reports some results on the relationship between R&D, value added and productivity for Norwegian firms.

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Appendix A: Definition of job creation rates etc.:

Let

$$\Delta N_{it}^{+} \equiv \begin{cases} 0 & : \quad N_{it} \leq N_{i,t-1} \\ N_{it} - N_{i,t-1} & : \quad \text{otherwise} \end{cases}$$

N_{it} = Average employment in plant "i" in year "t". See section 2.B .

and

$$N_t = \left(\sum_{i \in \Omega_t} N_{it} + \sum_{j \in \Omega_{t-1}} N_{j,t-1} \right) /2$$

where Ω_t is the set of all manufacturing plants in year t. The **total job creation rate**, θ_t^{JC}, is defined as:

$$\theta_t^{JC} \equiv \frac{\sum_{i \in \Omega_t} \Delta N_{it}^{+}}{N_t} \tag{3}$$

The total job creation rate can be divided into two parts:

- **Plant births** – summing only over new entrants in the numerator in (3) (i.e. replace the set Ω_t by the set of entrants; Ω_t^{entr}, in the summation in the numerator).
- **Plant expansion** – summing over expanding plants in the numerator in (3) (i.e. replace the set Ω_t by the set of continuing and expanding plants; Ω_t^{exp}, in the summation in the numerator).

The **total job destruction rate**, θ_t^{JD}, is defined correspondingly:

$$\theta_t^{JD} \equiv \frac{\sum_{i \in \Omega_t} \Delta N_{it}^{-}}{N_t} \tag{4}$$

where

$$\Delta N_{it}^{-} \equiv \begin{cases} N_{i,t-1} - N_{it} & : \quad N_{it} \leq N_{i,t-1} \\ 0 & : \quad \text{otherwise} \end{cases}$$

The total job destruction rate can also be divided into two parts:

- **Plant closing** – summing only over exiting plants in the numerator in (4) (i.e. replace the set Ω_t by the set of exiting plants; Ω_t^{exit}, in the summation in the numerator).
- **Plant contractions** – summing only over contracting plants, remaining in operation, in the numerator in (4) (i.e. replace the set Ω_t by the set of continuing and contracting plants; Ω_t^{cntr}, in the summation in the numerator).

The **gross job reallocation rate**, θ_t^{GJR}, is defined as:

$$\theta_t^{GJR} \equiv \theta_t^{JC} + \theta_t^{JD} \tag{5}$$

The **net job creation rate**, θ_t^{NJC}, is defined as:

$$\theta_t^{NJC} \equiv \theta_t^{JC} - \theta_t^{JD} \tag{6}$$

The four rates defined above (the job creation rate, the job destruction rate, the gross job reallocation rate, and the net job creation rate) can also be defined for a subset of manufacturing plants such as an industry, by restricting all summations above to the set of manufacturing plants belonging to, say, industry I: $\Omega_{It} \subset \Omega_t, \;\; I \in \Gamma$, where Γ is the set of all industries. The industry specific rates will be referred to with an additional subscript I, such as θ_{It}^{JC} etc.

Appendix B: Industry codes, names and classification

This is the list of the codes for manufacturing sectors considered in considered in this paper.

1 Manufacture of food, beverages and tobacco (ISIC 310-314)

2 Manufacture of textiles, wearing apparel, leather and leather products (ISIC 320-322)

3 Manufacture of wood and wood products, including furniture (ISIC 330-332)

4 Manufacture paper and paper products; printing and publishing (ISIC 340-342)

5 Manufacture of industrial chemicals (ISIC 350-352)

6 Petroleum refining, manufacture of products of petroleum and coal (ISIC 353-354)

7 Manufacture and repair of rubber products, and manufacture of plastic products (ISIC 355-356)

8 Manufacture of mineral products (ISIC 360-369)

9 Manufacture of basic metals (ISIC 370)

10 Manufacture of fabricated metal products (ISIC 380-381)

11 Manufacture of machinery (ISIC 382)

12 Manufacture of electronic equipments (ISIC 383)

13 Manufacture of transport equipment (ISIC 384)

14 Manufacture of professional and scientific instruments, photographic and optical goods (ISIC 385)

15 Other manufacturing industries (ISIC 390)

Technology. Industries are grouped on the basis of their RandD intensity in the OECD area as a whole, defined as the ratio (business-enterprise RandD to production. The following high-, medium- and low-technology groups emerge:[1]

High-technology. Aerospace (ISIC 3845), computers and office equipment (ISIC 3825), communication equipment and semicoı ductors (ISIC 3832), electrical machinery (ISIC 383 – 3832), pharmaceuticals (ISIC 3522), scientific instruments (ISIC 385).

Medium-technology. Chemicals excluding drugs (ISIC 351 + 352 – 3522), rubber and plastic products (ISIC 355 + 356), non-ferroı metals (ISIC 372), non-electrical machinery (ISIC 382 – 3825), motor vehicles (ISIC 3843), other transport equipment (ISI 3842 + 3844 + 3849), other manufacturing (ISIC 39).

Low-technology. Food, beverages, tobacco (ISIC 31), textiles, apparel and leather (ISIC 32), wood products (ISIC 33), paper an printing (ISIC 34), petroleum refining (ISIC 353 + 354), non-metallic mineral products (ISIC 36), iron and steel (ISIC 371), met: products (ISIC 381), shipbuilding (ISIC 3841).

Appendix C: Changes in competitiveness for Norwegian manufacturing, 1982-92

In this appendix, we will briefly consider changes in competitiveness for Norwegian manufacturing 1982-92, as measured by conventional variables such as the exchange rate, relative wage costs per unit of production etc. See Fagerberg (1988) for a critical analysis of such measures of competitiveness. Such indices are presented in figures C.1 and C.2 Fig. C.1 shows that the market share for exports declined in the mid-80s, but remained stable from 1986 onwards. This market share refers to exports from mainland production. Relative prices for Norwegian exports (excluding oil and gas) peaked in 1989. Fig. C.2 presents an index of competitiveness/rate of change in wage costs, i.e. relative wage cost per unit of production, and the real exchange rate. Considering the wage costs, there is first a stable period until 1986, followed by an increase in Norwegian wage costs in 1987 and 1988. From 1989 onwards, growth in wage costs per unit of production have been somewhat lower in Norwegian manufacturing than in the competing countries. We recognize that these estimates of Norwegian manufacturing competitiveness are not undisputed, and some revised estimates have been presented.

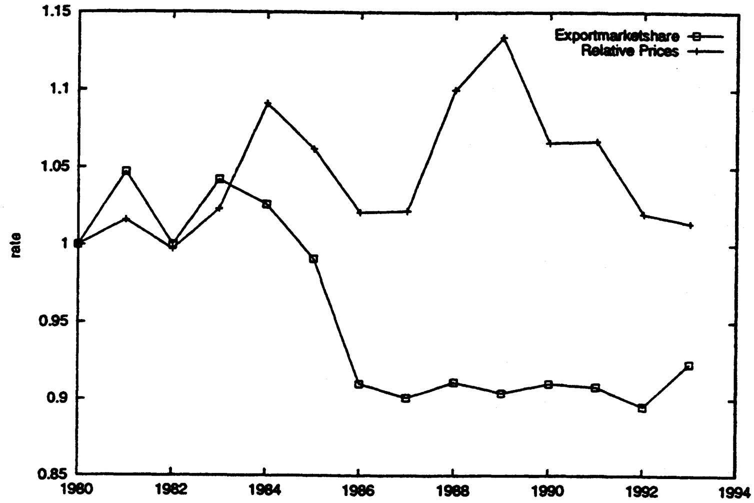

Figure C.1: Marketshare and relative (mainland) prices for Norwegian exports.
Source: Statistics Norway and International Monetary Fund.

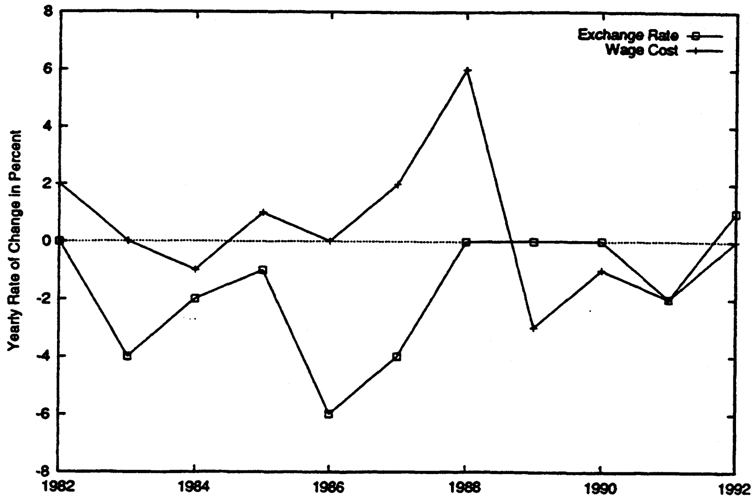

Figure C.2: Real exchange rate and an index for Norwegian competitiveness (relative wage costs per unit of production).
Source: Statistics Norway.

Table 1: Summary statistics for sample

Industry codes	All Plants #Plants$_{87}$	All Plants Employ-ment[1] (1987)	All Plants Empl. growth[2] (1982-92)	R&D Plants #Plants$_{87}$	R&D Plants Employ-ment[1] (1987)	R&D Plants Empl. growth[2] (1982-92)	Non-R&D Plants #Plants$_{87}$	Non-R&D Plants Employ-ment[1] (1987)	Non-R&D Plants Empl. growth[2] (1982-92)
1 Food. beverages and tobacco	968	46.1	-0.18	256	20.1	-0.14	712	26.0	-0.10
2 Textiles	232	10.7	-0.71	55	3.7	-0.77	177	7.0	-0.68
3. Wood products	497	20.8	-0.43	118	7.8	-0.58	379	13.0	-0.34
4 Paper products	596	41.0	-0.13	98	11.7	-0.28	498	29.3	-0.08
5 Industrial chemicals	138	14.6	-0.26	89	11.3	-0.33	49	3.3	0.10
6 Petrolium refining etc.	72	2.6	-0.23	23	1.6	-0.18	50	1.0	-0.32
7 Plastic products	144	6.8	-0.32	54	3.8	-0.39	90	3.0	-0.22
8 Mineral products	194	9.0	-0.38	83	4.9	-0.48	117	4.1	-0.26
9 Basic metals	91	22.6	-0.46	61	19.8	-0.51	30	2.8	-0.06
10 Metal products	410	20.0	-0.28	105	8.1	-0.49	305	11.9	-0.14
11 Machinery	483	38.5	-0.08	116	24.7	0.10	368	13.8	0.05
12 Electronic equipments	186	19.6	-0.46	115	16.4	-0.70	71	3.3	0.33
13 Transport equipment	256	22.0	-0.60	53	8.8	-0.71	203	13.2	-0.51
14 Scientific instruments	24	1.4	0.50	14	0.9	0.30	10	0.4	0.74
15 Other industries	42	2.1	0.31	13	1.1	0.46	29	1.0	0.18
Total manuf.	***4333***	***278.0***	***-0.27***	***1253***	***145.0***	***-0.36***	***3080***	***132.3***	***-0.18***

1) Numbers are reported in 1000s
2) Defined as $2*(N_{92}-N_{82})/(N_{92}+N_{82})$

Table 2: Estimated coefficient[1] on R&D-dummy in models 1-4[2].

Dependent variable	Time dummies		Time * ind. dummies		Time * (industry and size) dummies		Time * (for.comp. and size) dummies	
Net job creation[3]								
1982-86	0.44	(0.44)	0.06	(0.44)	0.31	(0.51)	0.25	(0.45)
1987-89	-0.84	(0.51)	-0.32	(0.48)	-0.72	(0.56)	-0.11	(0.49)
1990-92	-1.40**	(0.51)	-1.54**	(0.52)	-1.80**	(0.52)	-1.25*	(0.51)

** Significant at 1% level
* Significant at 5% level
1) Multiplied by 100.
2) Numbers in parantheses are heteroskedasticity consistent standard errors.
3) Transformed according to eq. (1).

Table 3: Estimated coefficients[1] on R&D-dummies in models 1-4[2].

Dependent variable		Time dummies		Time * ind. dummies		Time * (industry and size) dummies		Time * (for.comp. and size) dummies	
Net job creation[3]									
1982-86	LOW R&D	-0.07	(0.54)	0.41	(0.50)	-0.16	(0.57)	-0.60	(0.52)
	HIGH R&D	0.82	(0.60)	0.60	(0.67)	0.90	(0.73)	1.03	(0.60)
1987-89	LOW R&D	0.53	(0.43)	0.50	(0.45)	0.06	(0.53)	-0.93	(0.50)
	HIGH R&D	-1.88**	(0.75)	-1.28	(0.74)	-1.69*	(0.80)	-1.29*	(0.66)
1990-92	LOW R&D	-0.90*	(0.45)	-0.97*	(0.47)	-1.24*	(0.53)	-1.21*	(0.51)
	HIGH R&D	-1.85*	(0.80)	-2.25**	(0.80)	-2.51**	(0.85)	-1.29	(0.72)

** Significant at 1% level
* Significant at 5% level
1) Multiplied by 100.
2) Numbers in parantheses are heteroskedasticity consistent standard errors.
3) Transformed according to eq. (1).

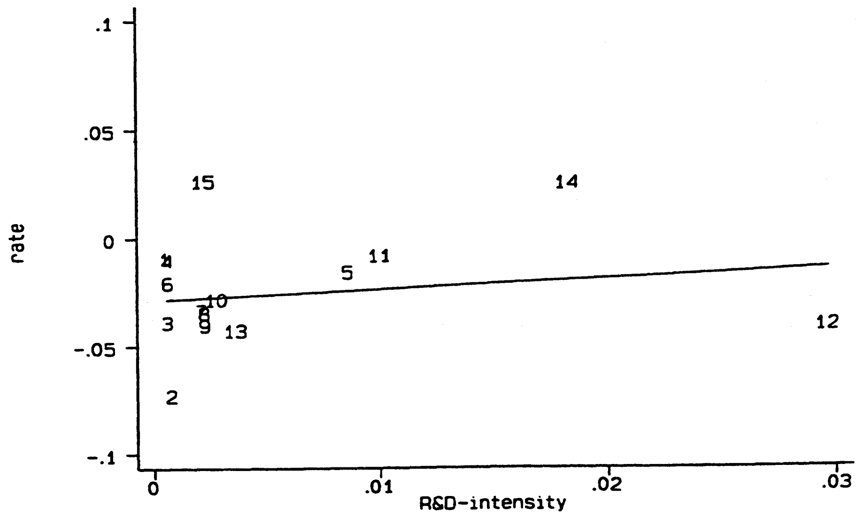

Figure 1: Net job creation vs. industri R&D intensity.
(The numbers refer to the sector codes explained in appendix B.)

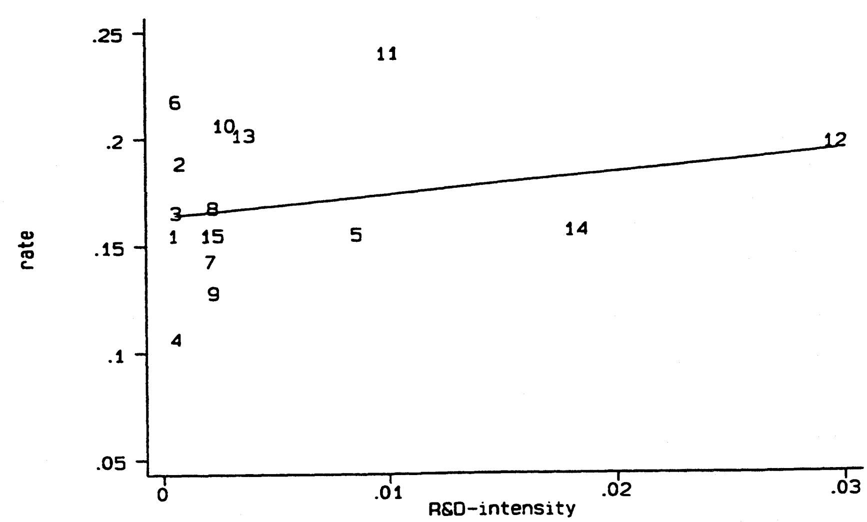

Figure 2: Job reallocation vs. industri R&D-intensity.
(The numbers refer to the sector codes explained in appendix B.)

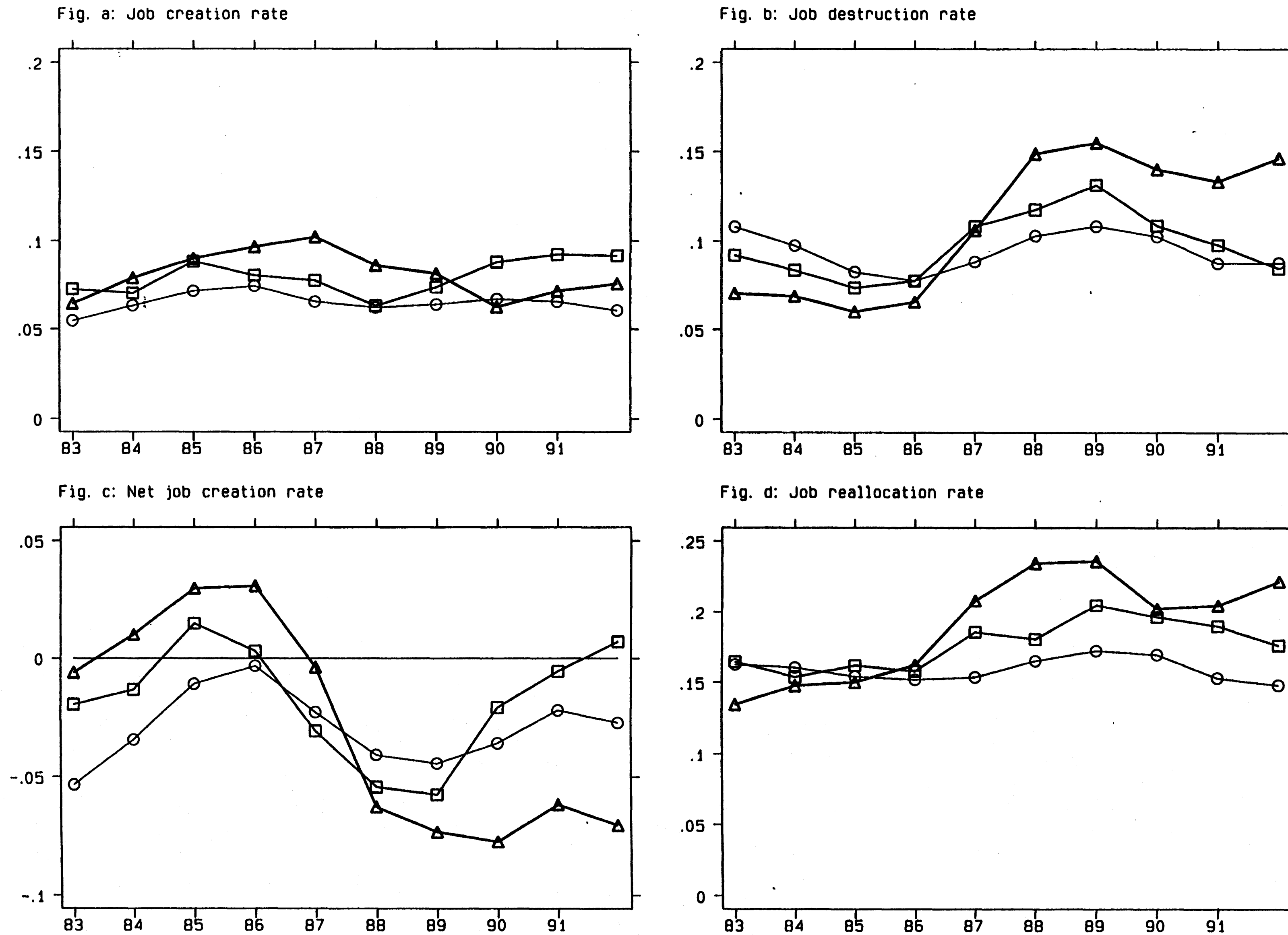

Figure 3: Job creation and destruction in low, medium and high technological industries compared (three year moving-averages).
Δ- High technological industries, □- Medium technological industries, o - *Low technological industries.*

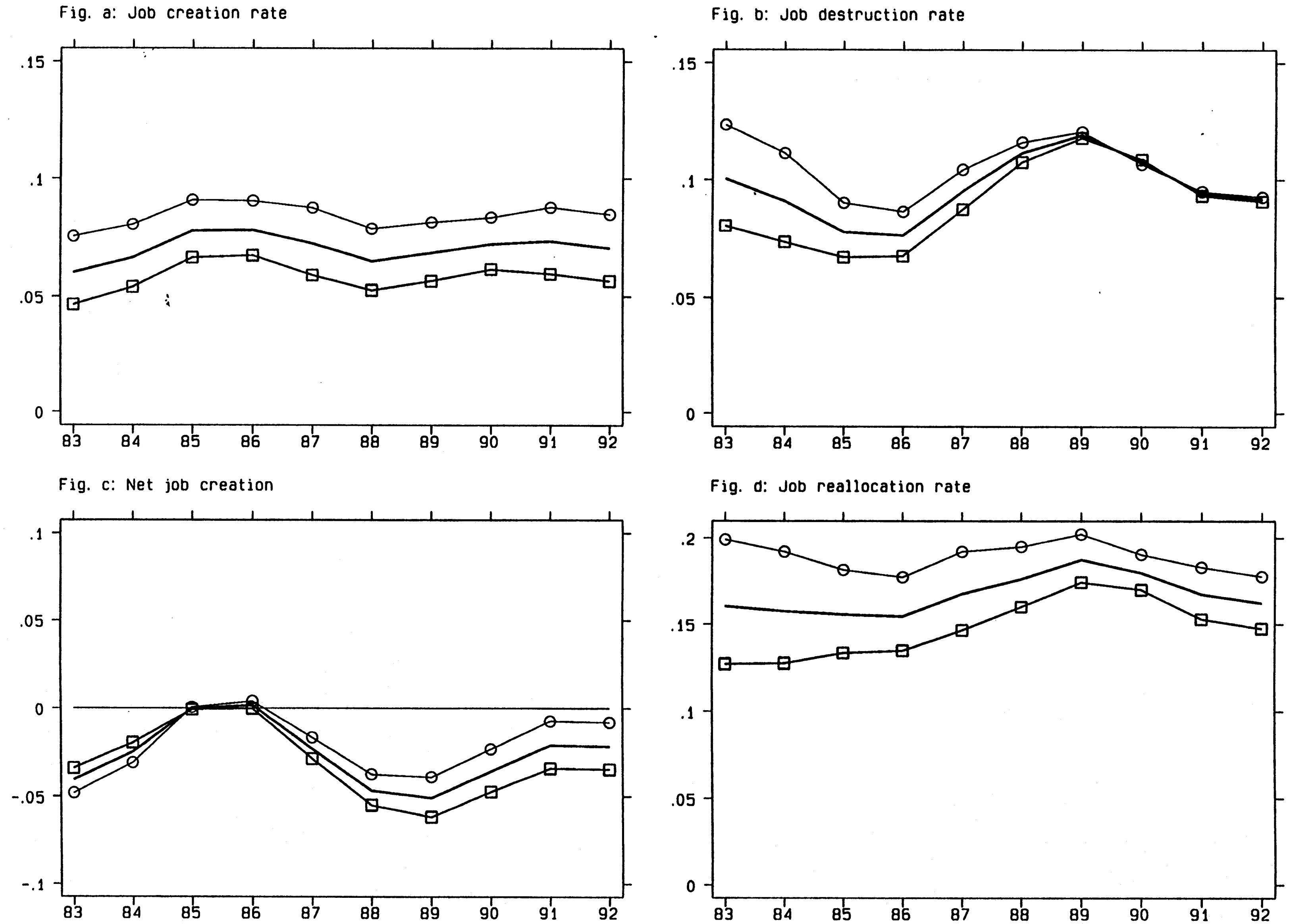

Figure 4: Job creation and job destruction in R&D- and no-R&D plants (three years moving averages)
□- R&D-plants, o - No-R&D plants, — All manufacturing plants

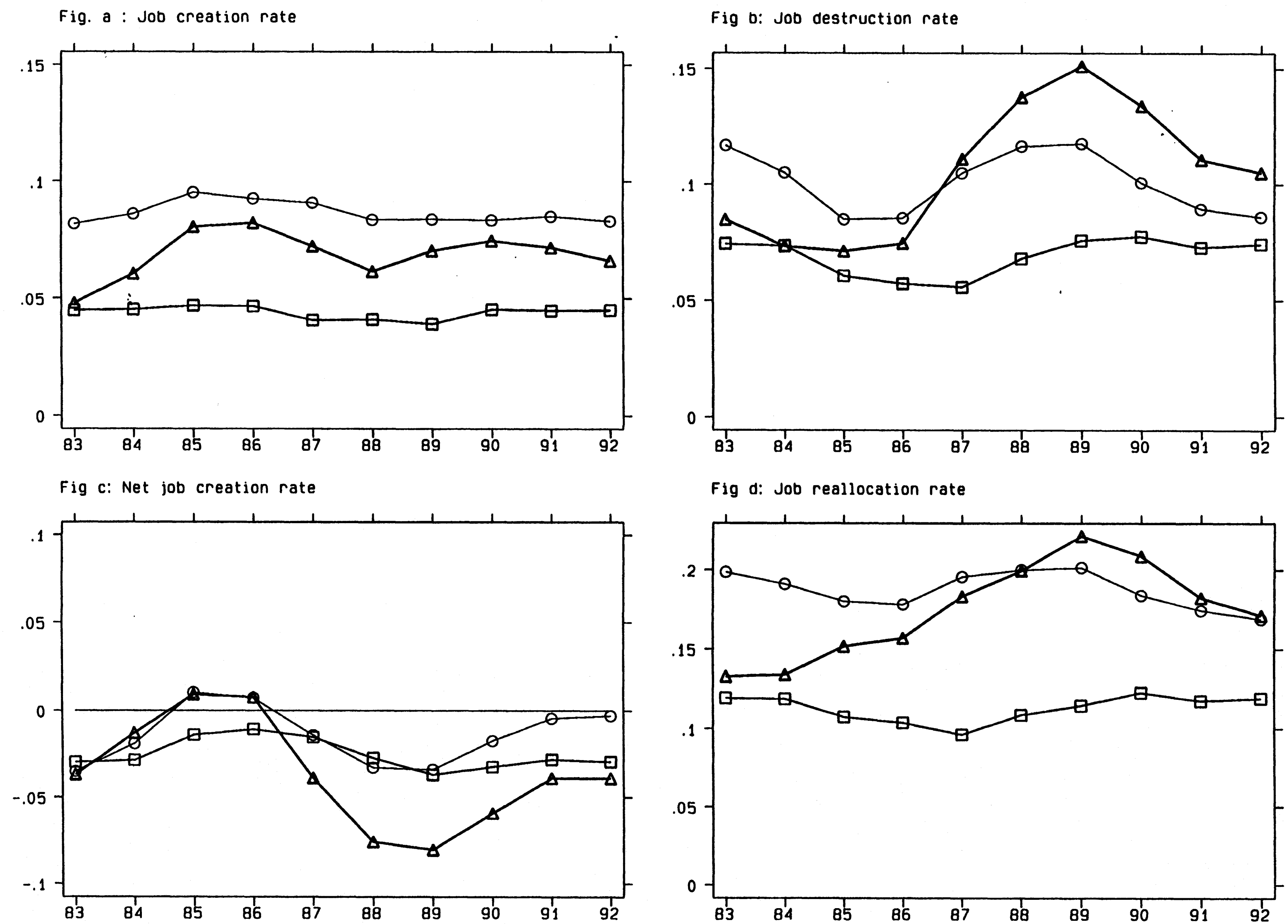

Figure 5: Job creation and job destruction for plants with different R&D-intensities (three years moving averages)
Δ - High-R&D plants, □ - Low-R&D plants, o - *No-R&D -plants*

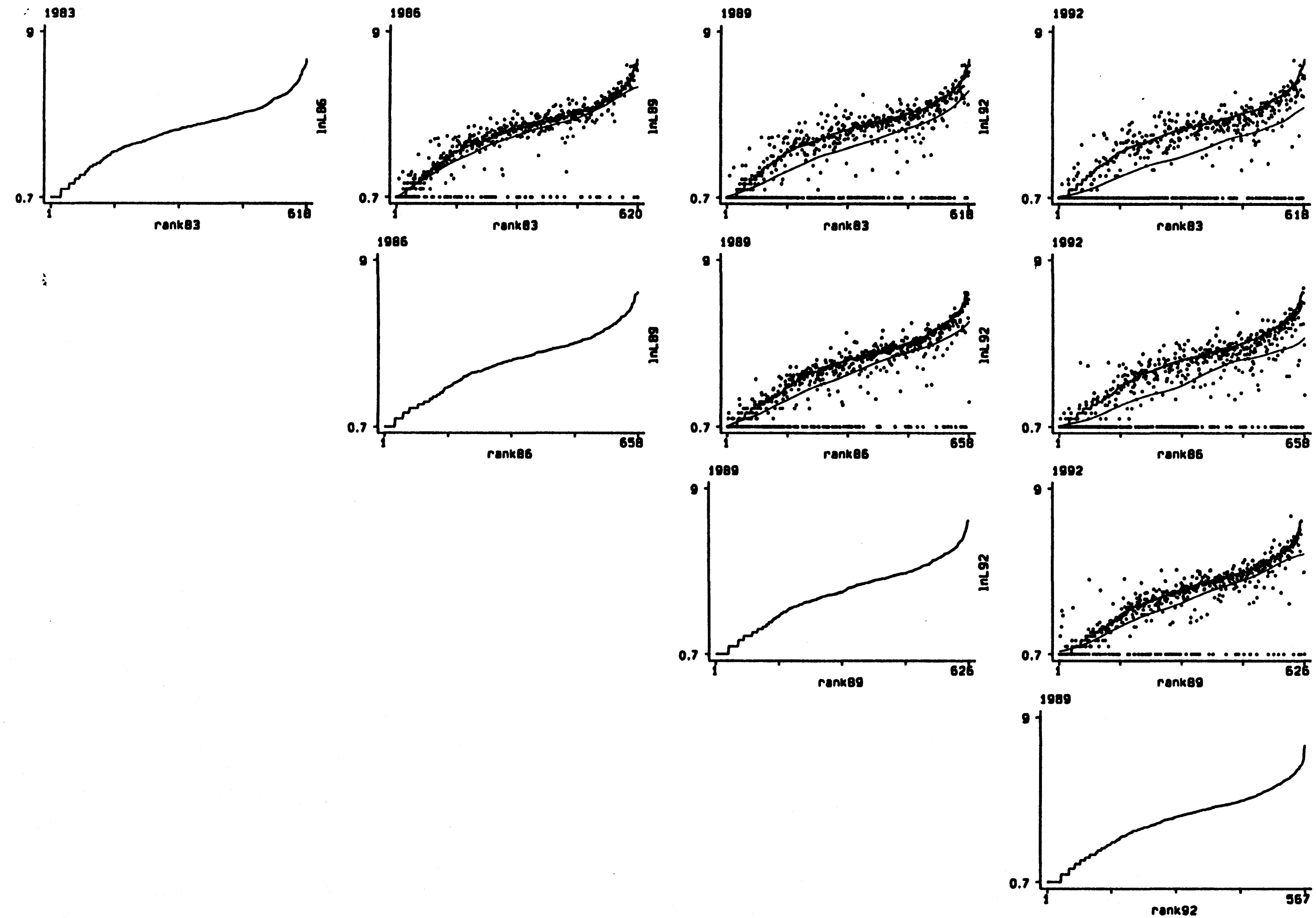

Figure 6: Cross profiles of log plant employment as a function af rank size in the years 1983, 86, 89, 92. Only high-R&D plants.

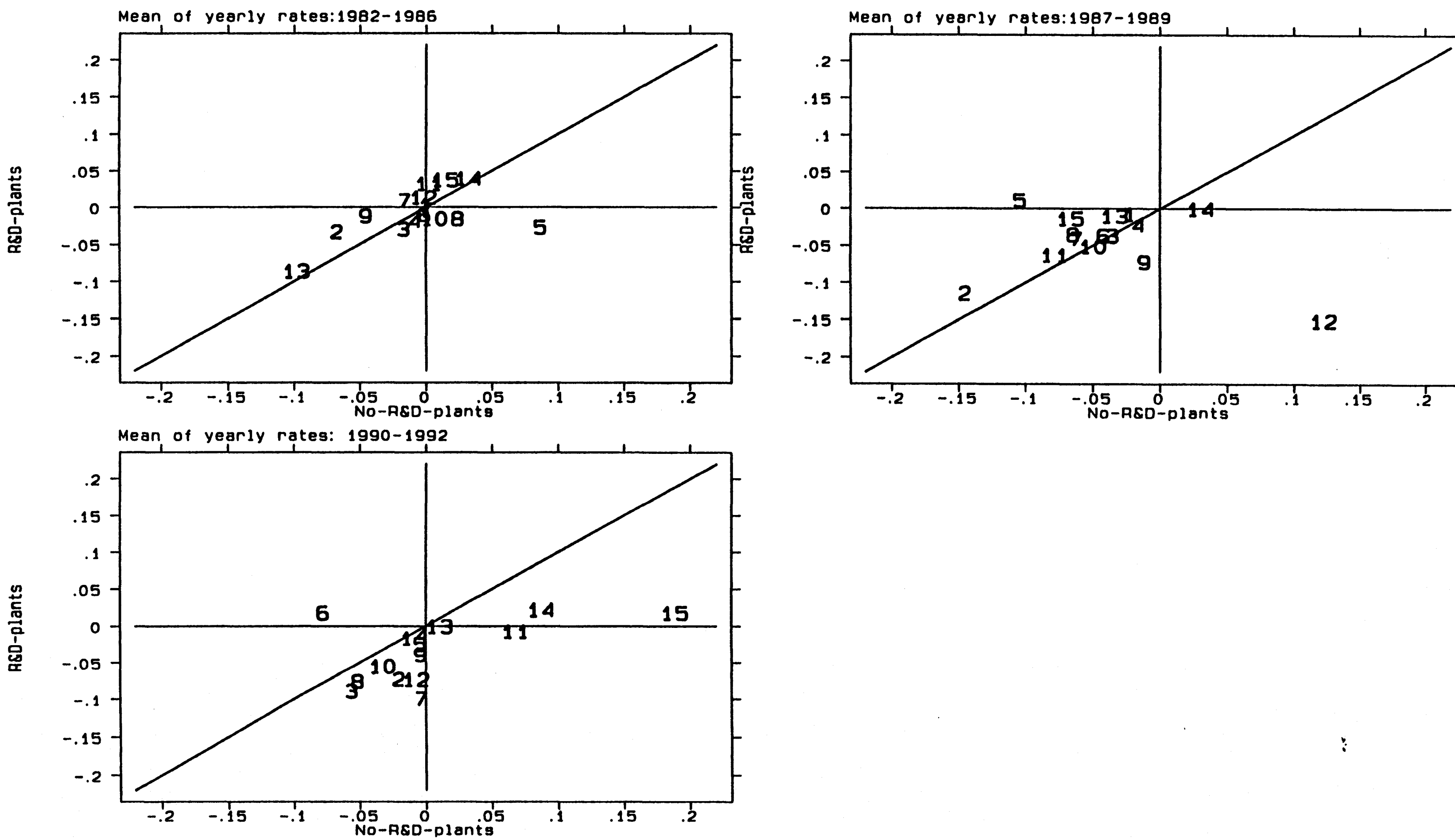

Figure 7: Net job creation rates for R&D vs. no-R&D plants by industry.
(the numbers refer to sector codes explained in appendix B)

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ISSN 0803-074X

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