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Keskusteluaiheita - Discussion papers

No. 357

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RETURNS TO R&D IN NORDIC MANUFACTURING INDUSTRIES, 1964 TO 1983

ISSN 0781-6847

20.03.1991

VUORI, Synnöve, **RETURNS TO R&D IN NORDIC MANUFACTURING INDUSTRIES, 1964 TO 1983.** Helsinki : ETLA, Elinkeinoelämän Tutkimuslaitos, The Research Institute of the Finnish Economy, 1991. 42 p. (Keskusteluaiheita, Discussion Papers, ISSN 0781-6847; no. 357).

ABSTRACT: The study examines the effects of the firms' own R&D efforts on total factor productivity in ten manufacturing industries in Finland, Sweden and Norway. The analysis is based on industry time series data. The results imply that the returns to R&D have in general not been as high as has generally been thought. Instead, technology diffusion seems to be important for almost all industries studied, but the evidence of a similar technology base in the three countries is not very strong.

KEY WORDS: Total factor productivity, R&D, diffusion, manufacturing industries, Finland, Sweden, Norway

RETURNS TO R&D IN NORDIC MANUFACTURING INDUSTRIES, 1964 TO 1983

Contents:

1. INTRODUCTION*)**)

Technology inputs, which are acknowledged to improve firms' productivity and competitiveness, can be classified into three groups according to their source (see Figure 1): a) Research and development performed by the firms themselves, b) transactions-based technology (technology embodied in intermediate and capital inputs, plus technology received through patents, licences etc.), and c) other diffusion of technology (including learning from others - and also from their and own mistakes, learning by doing, knowhow received by recruiting personnel from other firms, and education). Of these, a) may be called direct technology inputs, and b) and c) indirect technology inputs.

This paper is one stage in a larger research project, where the ultimate goal is to analyse the effects of R&D and diffusion of technology on productivity. This stage focusses on the direct technology inputs, and compares the performance of ten manufacturing industries across three Nordic countries (Finland, Sweden and Norway). The results are to be used later on in another study, where also technology embodied in intermediate and capital inputs will be taken into account.

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*) This paper is part of a larger research programme focussing on diffusion of technology and industrial transformation in Finland, partly financed by TEKES (The Technology Development Centre).

**) I am indebted to Pekka Ylä-Anttila, Vesa Kanniainen and Esko Torsti for useful comments on an earlier draft.

Figure 1. Sources of technology in output.

Indirect technology inputs:	Direct technology inputs:
* Technology in intermediate inputs - Domestic - Imported * Technology in capital inputs - Domestic - Imported * Other transactions-based technology - Patents, licences etc. * Other technology diffusion - Education, learning etc.	* R&D by final producer

↓ ↓

Total technology embodied in final output

Source: Developed on the basis of Davis 1988.

It is generally acknowledged that technology diffusion is vitally important for small economies. Moreover, it is to be expected that the roles of direct and indirect technology inputs are different in different industries. In some sectors intensive investment in own research is essential, whereas for others the main technology advances come from outside the firm or sector, especially from innovations and improvements made by producers of intermediate and capital goods used in that sector. Therefore, to facilitate the assessment of the results to be presented in this paper, the industries studied have been preliminarily classified on the basis of their own research intensity (Table 1).

Since average research intensity in a given industry varies across countries -

with Sweden having in general clearly higher intensitities than Finland and Norway - the classification is based on a comparison of a given industry's intensity and the intensity of total manufacturing in the same country. Other manufacturing, which is a highly heterogenous group of producers, was classified as a medium-intensity industry in Finland and Sweden, but low-intensity in Norway. For Norway the R&D data was not available separately for printing and publishing. The other industries fall easily into the same intensity classes across countries, although as mentioned above, there are differences in the levels of the intensities.

Table 1.
Manufacturing industries classified on the basis of research intensity (relative to each country's manufacturing average), 1964 to 1983 average

	Research intensity, %		
	Finland	Sweden	Norway
HIGH RESEARCH INTENSITY			
- Chemical industries	1.01	1.86	0.84
- Basic metal industries	0.71	1.55	0.76
- Metal products and engineering	1.37	3.01	1.42
MEDIUM RESEARCH INTENSITY			
- Paper and paper products	0.55	0.84	0.31
- Non-metallic mineral products	0.40	0.88	0.28
- Other manufacturing	0.30	0.75	
LOW RESEARCH INTENSITY			
- Food, beverages and tobacco	0.14	0.33	0.09
- Textiles, clothing and leather	0.11	0.29	0.16
- Wood and wood products	0.09	0.08	0.13
- Printing and publishing	0.03	0.06	
- Other manufacturing			0.13
TOTAL MANUFACTURING	0.58	1.60	0.63

Source: The research intensities data are from Vuori (1988). Research intensity equals R&D expenditures divided by gross output.

The motivation behind Table 1 is that in industries with high research intensity, own research is expected to be more important in achieving better performance (measured here by increased productivity), whereas technology flowing from outside sources - or technology diffusion - is expected to be more important in industries with low research intensity. Thus, in all three countries the chemical industries, the basic metal industries and the metal products and engineering industry are expected to obtain relatively higher returns on their own research as compared with the effects of technology from outside sources. In contrast, the effects of indirect technology inputs are expected to dominate in the food, textile and wood industries.

The purpose of the paper is thus to assess the returns to the firms' own R&D investments in the various industries, to preliminarily assess the relative roles of diffusion and own research, and to compare the developments in the three Nordic countries. The background hypothesis is here that the technological base for each industry is roughly the same in all three countries, especially as they are relatively similar as to size, geographical location, and social and economic developments, and as technology diffusion is regarded as the perhaps most important channel of technical change in small open economies. This should be seen in the form of roughly the same kind of behaviour of the rates of return to R&D, in the sense that the basic variability of rates of return is between industries, and not between countries.

Specification of the model

The paper follows the methodology used in an earlier paper (Vuori 1986), where the returns to R&D in Finnish and Swedish manufacturing industries were analysed, but uses a larger data set. First, the data contain three additional yearly observations, so as to consist of the period 1964 to 1983 for the basic analyses. Second, in addition to Finland and Sweden, data for the corresponding ten manufacturing industries in Norway were included in the study. This larger data set is presented and described in another paper (Vuori 1988). While most previous work on the relationship between R&D and productivity has been made on a cross section basis, this paper (and Vuori 1986) uses time series, and is made separately for each industry.

In the model that we have used, changes (f) in total factor productivity (TFP) are explained by the changes in the research capital stock (R) and changes in the rate of utilization of fixed assets (u). Thus

$$f_t = a + b \hat{R}_{t-i} + c\hat{u}_t , \qquad (1^*)$$

where a is the constant term reflecting autonomous technological change, and ˆ denotes relative changes (or logarithmic differences). The model follows the standard approach used by Terleckyj (1980), Griliches (e.g. 1980) and many others, except that since time series are used instead of cross sections, the effects of fluctuating capacity utilization have to be taken into account. To quote Griliches and Lichtenberg (1984, p. 476): "We postulate that the level of the R&D stock is a determinant of the trend component of TFP, but not of its short-run deviations from trend; the latter are primarily the result of fluctuations in capacity utilization."

The measure of changes in TFP is based on a fairly general gross output translog production function (y), including a set of inputs (labour, capital and materials), plus research capital as an additional factor causing technological change. We then have

$$y = \exp(\ln F(X_n)).g(t), \tag{2*}$$

where y is output, $F(X_n)$ is a factor requirements function with three inputs, and g(t) is a function describing Hicks neutral technological change

$$g(t) = e^{at}R^{b}. \tag{3*}$$

R represents research capital, and a is the rate of autonomous technological change. From (2*) and (3*) we can derive the expression for changes in total factor productivity:

$$f = \hat{y} - \Sigma\, w_n \hat{X}_n = a + b\hat{R} \tag{4*}$$

where the inputs X are weighted by the mean of the current and previous periods' value shares. It follows from the model that the coefficient b in Eq. (4*) is the output elasticity of research capital. Assuming that research capital does not depreciate, b can be decomposed into two multiplicative terms, the marginal productivity of research capital (or the rate of return to research capital), v, and research intensity (R&D expenditures divided by output, r/y), since current R&D in this case equals the change in R&D capital /See Vuori 1986 for further details./:

$$f = a + b\hat{R}$$
$$= a + \delta y/\delta R.\bar{R}\ /y\ = a + v.r/y \qquad (5^*)$$

Moreover, the rate of return based on this kind of model is interpreted as an excess rate, on top of usual factor incomes, since in general research inputs cannot be separated from labour and capital input and are thus included twice in the calculations. /See e.g. Schankerman 1981 and Griliches and Lichtenberg 1984./

Next, the effects of fluctuating capacity utilization are added to the model. Defining the rate of capacity utilization as actual output divided by potential output, or $u = y/y^P$, we obtain the relation between actual changes in TFP and changes corresponding to full capacity levels (f^P):

$$f = f^P + \hat{u}. \qquad (6^*)$$

Assuming that potential output is produced with the input combination $\Sigma\ w_n\ \hat{X}_n$ and actual output with the combination $\Sigma\ h_n\ \hat{Z}_n$, where the h_n's are observed value shares, we have

$$f = f^P + \hat{u} - (\Sigma\ h_n\ \hat{Z}_n - \Sigma\ w_n\ \hat{X}_n\ ), \qquad (7^*)$$

that is, the change in below full capacity productivity equals the sum of changes in full capacity productivity and utilization, minus the expression in brackets, the difference between the weighted observed and full capacity input changes. Since this expression cannot be observed, we make the intuitively appealing assumption that it is a function proportional to the change in the rate of utilization, or $g\hat{u}$. With

$$f^{P} = a + b\hat{R} \tag{8*}$$

we then have

$$f = a + b\hat{R} + (1-g)\hat{u}, \tag{9*}$$

which, since previous research /e.g. Ravenscraft and Scherer 1982, Pakes and Schankerman 1984, and Vuori 1986/ has indicated that the lags connected with the effects of research inputs on productivity can be several years long, was modified to the form

$$f_t = a + b\,\hat{R}_{t-i} + c\hat{u}_t\ . \tag{1*}$$

In the study experiments are made to determine the most suitable lag length for each of the ten industries studied, the lag length ranging from zero to six years. The experiments also focus on the issue of which would be the suitable depreciation rate for research capital, since there is no unanimity on this either /See e.g. Griliches 1979 and 1980b./. We thus started off with the zero depreciation rate and continued with the rates 0.1 and 0.2. These experiments are evidently not based on any theory, and thus we will not claim to have found the final truth, but instead we are trying to shed some additional light on the form of the relationship between R&D and productivity.

In the following section the most interesting results of these experiments are reported for each industry separately. Since it is known from previous studies that the capacity utilization variable has a dominant role in explaining productivity fluctuations, we will comment on its role only occasionally.

2. EMPIRICAL RESULTS

FOOD, BEVERAGES AND TOBACCO

In the food, beverages and tobacco industry research intensity is very low on average. This is matchéd by productivity developments clearly below the total-manufacturing average in all three countries studied here.

The regressions that were run using the three different depreciation rates for R&D capital (0, 0.1 and 0.2 respectively) showed that for all three countries, the "best" results (in terms of R^2's and t-values for individual coefficients) were obtained when using the 0.2 depreciation rates, although the results were qualitatively fairly similar as when using the zero depreciation rate. In the following we are referring to the results from the 0.2-depreciation cases.

For Finland the constant term, which according to theory should represent autonomous technological change, was positive for all model varieties,each containing one research capital term (lagged or not, with the lags ranging from zero to six years). In these model varieties, or equations, the constant term was also significant when using lag lengths 0, 3 and 6 years for the research capital variable. However, the model with the highest R^2 was with a lag of 5 years, and in this case the coefficient of the research capital variable was positive and approximately significant at the 5 per cent level.

For Sweden and Norway the constant term did not yield significant values for any of the lags used. Instead, the R&D variable was positive and significant for a lag of one year in Sweden, and two years in Norway. The coefficient of the capacity utilization variable is clearly significant for all lags and all countries. A striking thing is, however, that it is much less significant for the Swedish food industry than for the other two countries, and also compared with most of the other industries analysed in this paper, and in this case also the R^2's are much lower than in general in these analyses. Thus, it seems that for Sweden there must be some other factor strongly influencing total factor productivity, which has not been dealt with here.

Table 2.
Selected regression results for the food industry, 1964-83

Eq. no.	Country	Lag (i)	Depreciation rate	Constant	$\hat{u}$	$\hat{R}_{t-i}$	R^2	D-W
(1)	Fin	0	0.2	.389 (2.061)	.157 (8.197)	-.007 (-.286)	.7981	1.964
(2)	Fin	3	0.2	.560 (2.385)	.147 (6.867)	-.030 (-.974)	.8079	2.010
(3)	Fin	5	0.2	.011 (.053)	.151 (8.067)	.048 (1.673)	.8300	2.110
(4)	Fin	6	0.2	.509 (2.156)	.158 (7.635)	-.021 (-.643)	.8068	2.101
(5)	Swe	1	0.2	-.255 (-1.350)	.118 (2.629)	.052 (2.237)	.4395	2.130
(6)	Nor	2	0.2	.076 (.691)	.174 (6.905)	.054 (2.288)	.7413	2.574

Note. t statistics in brackets below the coefficients, DW = Durbin-Watson statistic.

It can thus be cautiously concluded that in this industry the firms' own research efforts seem to have a positive effect on productivity, the time lag of this effect ranging from one to five years. While plausible as such, a five-year lag should be regarded only as a preliminary result, since our time series are fairly short. In Finland also technology coming from outside sources, or technology diffusion, seems to be important, although its role relative to that of the firms' own research remains unresolved. Thus, there are differences between the three countries (contrary to expectations), the results concerning Sweden and Norway suggest that low research intensity as such does not necessarily mean that technology diffusion would be more important than own research (also contrary to expectations).

TEXTILES, CLOTHING AND LEATHER

The textile, clothing and leather industries have experienced a period of strong decline in most industrialized countries in the 1970s and 1980s, both in terms of the absolute level of output and employment, and of the relative weight of these industries, as expressed e.g. by their share in total manufacturing value added. The Nordic countries have followed the same trends (see e.g. Table 2 in Vuori (1988)), although the decline has not been quite continuous. In Finland the decline started later than in many other countries, partly due to favourable growth of exports to the Soviet Union in the 1970s and the early 1980s (see e.g. Vuori and Ylä-Anttila 1988). At the same time, total factor productivity slowed down in the second half of the period 1963-83 to practically zero on average in Sweden and Norway.

It is thus interesting to look at the relationship between technology inputs (here: changes in the research capital stock) and changes in productivity, as an application to the more general question of what the role of technological change is for declining industries, i.e. can it help in solving the problems of these industries. Since own research intensity is very low in this sector, most of its technological advance is thought to come from outside the sector, especially through improved machinery.

The results of the regressions run for this industry aggregate are somewhat surprising. Taking Finland first, the models with the zero-depreciation research capital stock, varying its lag length from 0 to 6, behaved on the whole fairly nicely. That is, contrary to many other industries being studied here, the constant term representing autonomous technological change (in addition to the change in capital utilization) was positive and in most cases significant for each of the lag lenghts. As to the technology variable, it received negative and non-significant coefficients at lag lengths 0,1,2 and 4, positive non-significant coefficients at lag lengths 3 and 5, and finally, a positive and clearly significant coefficient at lag length 6 years. Of course, we cannot be quite confident with such a long lag length, since the data are fairly short, but at least there seem to be some indications of a positive rate of return on technology inputs.

For Sweden the results are somewhat different. While the capacity variable receives a positive and significant coefficient for all equations containing a different lag of the R&D stock variable, the constant term has a negative (i.e. non-expected) sign in each case. More importantly, the R&D variable itself receives a positive and significant coefficient both for lag lengths 0, 1, 2, 4 and 5, and a positive coefficient for lags 3 and 6 also. Thus here the positive relationship between technology and productivity seems to be very stable, although the results imply the possibility of misspecification of the model, as far as the lag structure of the technology variable is concerned.

For Norway the model using zero depreciation of R&D and different lag lengths does not fit with the data at all, and the R^2's are very low indeed. Closer examination of the data reveals, however, that this may be due to the strong decline of the industry. Thus, a growing research capital stock is perhaps not a good description of reality, even if the flow of research has continued each year. Instead, with a substantial number of firms and employees leaving the industry, it is more plausible that some part of previous knowledge stock must have become obsolete. Thus it seemed important to experiment with models containing the research capital variable with 0.1 and 0.2 annual depreciation rates respectively. And indeed, the results improved substantially, although the coefficients of determination remained fairly low, implying a possible omitted variable problem.

With a 0.1 depreciation rate, the technology variable did not receive a significant coefficient with any of the lag lengths examined, except a nearly significant - but negative - one with lag length 5. Instead, the constant term and the capacity variable had positive and significant coefficients with lag lengths 0, 1, 2, and 3. As to the 0.2 depreciation rate and one-year lag case, the constant and the capacity variable received positive but non-significant coefficients and the technology variable had a significant coefficient, but the test statistics suggest the presence of negative autocorrelation. Here again, lag length 5 produced a near-significant negative coefficient. Thus it would be tempting to speculate that research capital has become obsolete fairly rapidly in this industry in Norway, but so far more evidence for this is needed.

Table 3.
Selected regression results for the textiles and clothing industry, 1964-83

Eq. no.	Country	Lag (i)	Depreciation rate	Constant	$\hat{u}$	$\hat{R}_{t-i}$	R^2	D-W
(7)	Fin	0	0	2.104 (3.962)	.213 (7.116)	-.121 (-1.434)	.7617	1.829
(8)	Fin	6	0	.504 (1.137)	.182 (6.869)	.128 (1.849)	.7863	1.939
(9)	Swe	2	0	-2.199 (-1.389)	.203 (2.944)	1.088 (2.371)	.5146	2.174
(10)	Swe	5	0	-2.829 (-1.525)	.181 (2.333)	1.180 (2.341)	.5095	2.285
(11)	Nor	2	0.1	1.404 (5.565)	.084 (1.789)	.119 (1.001)	.2287	2.424
(12)	Nor	1	0.2	.448 (1.008)	.011 (.136)	.193 (1.743)	.1539	2.951

Note. t statistics in brackets below the coefficients, DW = Durbin-Watson statistic.

To sum up, there seems to be a relationship between technology and productivity in the textile and clothing industry in all three countries, but this relationship is somewhat different in each. A strongly positive constant term - as in the case of Finland and Norway - would according to theory imply a strong positive effect of technological change in sources outside the firms or the industry. This would fit very well with the widely-recognized fact that this industry - and especially the clothing sector - is a supplier-dominated industry with relatively little own research effort. Why the situation should be different in Sweden - own research having a positive rate of return but technology diffusion not seeming to be important - remains so far unresolved. It could be a consequence of dealing with an aggregate, within which the textiles and the clothing sectors behave differently over the years, and probably also have different relative sizes in the three countries. This would, however, need closer analysis.

WOOD AND WOOD PRODUCTS

The wood and wood products industry is technologically characterized by its very low own research intensity, which is among the lowest (if not the lowest) across the various manufacturing industries. It is thus another example of a sector, where the most important part of technological advance comes through technology embodied in capital goods.

The regressions that were run on this industry reveal that the relationship between technology and productivity is somewhat different in the three Nordic countries. According to theory, the importance of technology sources outside the industry should be reflected in a strongly positive constant term in the regression equations. And indeed, for Finland the constant is practically always clearly positive in the period 1964 to 1983, with almost all lags ranging from zero to six, and with depreciation rates of R&D capital from 0 to 0.2. The "best" equations were obtained with the depreciation rate of 0.2 (Table 4), and as is typical of a capital-intensive sector, the coefficients of the capital utilization variable were systematically highly significant and positive.

However, the behaviour of the R&D capital variable is somewhat more puzzling. Its coefficient is mostly negative, but positive for lags 2 and 4. Moreover, the coefficient is positively significant for lag 2, and just as much negatively significant for a lag of five years. In the latter case the constant is also clearly significant. On the other hand, when the zero rate of depreciation for R&D capital was used, there was no positively significant coefficient for that variable, but instead the coefficients connected with lags of 3 and 5 years were negative and significant. Therefore, the nature of the relationship between R&D capital and productivity remains somewhat ambiguous with this kind of model specification, and should be analyzed more carefully.

For Norway the first results for the period 1964 to 1983 were such that except for the utilization variable, there were no significant coefficients for any lags or depreciation rates being experimented with. However, it was noticed that the first years of the data contain an outlier, and thus the regressions were repeated for the period 1967 to 1983, with much better results. Here, with depreciation rate 0.1, the constant is always positive, and significant for lag lenghts 3 and 4 years. The coefficients of the R&D variable are instead always negative, and significant for the same lag lengths. The interpretation of these results would thus be that, in line with expectations, outside sources of technology are important, and that, despite the low level of own R&D efforts, their return has been lower than the return on capital investment.

The results for the Swedish wood and wood products industry are again different. Using the zero depreciation rate for R&D capital, the constant terms are, except for lag length 5, always negative, and significant for the lag length of 1 year. Even if it could be accepted that without own research, the industry would suffer from technological retardation and a decrease in productivity, the value of the constant term (4 per cent) is too high to be plausible. The coefficients of the R&D variable are always positive, and significant for lag lengths 1, 2 and 3 years. For the two alternative depreciation rates, the coefficients of the R&D variable were never significant. The conclusion of a positive (excess) rate of return would thus require closer analysis, and respecification of the model.

Table 4.
Selected regression results for the wood and wood products industry, 1964-83

Eq. no.	Country	Lag (i)	Depreciation rate	Constant	$\hat{u}$	$\hat{R}_{t-i}$	R^2	D-W
(13)	Fin	2	0.2	.264 (.821)	.201 (13.185)	.042 (1.846)	.9111	1.800
(14)	Fin	5	0.2	1.362 (3.897)	.193 (12.237)	-.043 (-1.8267)	.9134	2.175
(15)	Swe	1	0	-4.063 (-2.040)	.266 (6.799)	1.398 (2.443)	.7535	1.390
(16)	Nor *)	4	0.1	.345 (1.800)	.262 (5.219)	-.156 (-2.619)	.8007	2.151

Note. t statistics in brackets below the coefficients, DW = Durbin-Watson statistic.
*) Observations 1967-83

As a preliminary conclusion we may thus state that the model specification that we have used does not seem to capture satisfactorily the relationship between R&D and productivity in the wood and wood products industry. Furthermore, this relationship also seems to be different across the three countries, which is not in accordance with our basic hypothesis.

PAPER AND PAPER PRODUCTS

The paper and paper products industry (ISIC 341) has a relatively high share in total manufacturing output in Finland, and is fairly important in Sweden and Norway too. This industry is an example of a sector, where the production process demands a high level of knowledge, but where nevertheless the major technological advances come from the capital goods supplying firms outside the sector itself. Thus research intensity in the paper industry has not been among the highest in manufacturing, although parts of it have clear high-tech industry characteristics. Indeed, research intensity has even declined in Finland and Norway during the period studied here (1964-83), whereas in Sweden the opposite trend prevailed.

The results of the regressions run on this industry are interesting. The three countries have certain characteristics in common as to how the basic model relating technological change to productivity fits with the data. First, the by far dominating effect, and in the Finnish and Swedish cases even more clearly than for any other industry studied here, on productivity changes comes from fluctuations in capacity utilization. This is of course natural in a very capital-intensive industry. Second, as is to be expected according to theory, the constant term is positive and in almost all cases (the cases meaning all 3 countries, 3 different depreciation rates of R&D capital, and lags ranging from 0 to 6) significant at the 5 per cent level. While the constant is expected to be positive in the rest of the industries also, this is not always the case. As to the paper industry, the "right" behaviour of the constant term, reflecting "autonomous" technological change, can be seen as further evidence of the substantial role of techlogical advance flowing to the firms from outside sources, and in this case especially from the machinery-supplying industry.

The behaviour of the research capital variable, reflecting the firms' own research efforts, is somewhat more puzzling. First, the experiments with different depreciation rates (0, 0.1 and 0.2) of the research capital stock led to the conclusion that for Finland and Sweden, a depreciation rate of 0.1 seemed to yield the best fit, whereas for Norway the "best" rate was zero. The most striking thing is, however, that for Sweden the coefficient of $\hat{R}_{t-i}$ was always negative and significant (or almost) at the 5 percent level (for all lags from 0 to 6). This can be seen as an indication of an incorrect specification of the lag structure, but also as evidence of a fairly clear negative dependence between the own-technology variable and productivity. Since the rates of return based on this relationship should be interpreted as excess rates (see Section 1), this means that in Sweden the rate of return on own R&D efforts has been lower than the return on fixed capital, or in other words too much has been spent on R&D relative to machinery.

For Norway the situation is fairly similar, with systematically negative coefficients of $\hat{R}_{t-i}$, except that (in the case of 0-depreciation), they are significant only with lag lengths 0 and 3. For Finland, the coefficients associated with different lag lengths behave less systematically, being sometimes negative, sometimes positive. An approximately-significant positive coefficient was found for lag length 6, but this should not be taken as definitive evidence of a positive excess rate of return, because of the uncertainties related to the shortness of the data.

Table 5.
Selected regression results for the paper industry, 1964-83

Eq. no.	Country	Lag (i)	Depreciation rate	Constant	$\hat{u}$	$\hat{R}_{t-i}$	R^2	D-W
(17)	Fin	0	0.1	.482 (3.472)	.228 (13.802)	-.276 (-1.427)	.9330	1.207
(18)	Fin	6	0.1	.391 (2.591)	.228 (13.397)	.375 (1.714)	.9399	1.538
(19)	Swe	0	0.1	2.492 (4.115)	.308 (14.536)	-.260 (-2.847)	.9463	1.344
(20)	Nor	3	0	2.339 (3.749)	.242 (8.717)	-.389 (-2.221)	.8221	2.059

Note. t statistics in brackets below the coefficients, DW = Durbin-Watson statistic.

Intuitively, however, a higher (relative to the return on fixed capital) rate of return on own research in Finland than in Sweden would seem plausible to some extent, because of the possibility of diminishing marginal returns, and of the Swedish paper industry having increased its research efforts relatively more. However, a fairly large difference between Finland and Sweden, as the results would indicate, would perhaps need further explanation, especially in view of the importance of this industry for both countries. It might be useful, for instance, to investigate the role of the industry's research institutes in both countries, since it may be different e.g. concerning the division of labour between them and the firms.

PRINTING AND PUBLISHING

Printing and publishing is one of the sectors, where total factor productivity grew more slowly than the average for the manufacturing industries during the period 1964-83 in all three countries, while at the same time output growth was faster than the manufacturing average both in Finland and in Norway. In fact there was a productivity decline in Norway in all but a few years, which would require some sort of explanation. Unfortunately, however, the analysis of the effects of R&D on productivity could not be done for Norway because of data problems.

For Sweden the results for printing and publishing are strikingly similar as those for the paper industry. The "best" fit was obtained with a 0.1 depreciation rate for R&D capital, even though the results with a 0.2 rate came very close, implying perhaps that the "true" depreciation rate could lie somewhere between 0.1 and 0.2. As with the paper industry, both the constant term and the capacity variable coefficient were systematically positive and highly significant with all lag lengths, with the coefficient of the latter not quite as significant as for the paper industry. Also, the coefficient of the R&D variable was systematically negative, and significant for lag lengths ranging from 0 to 3.

When interpreting these results it should be borne in mind that there is an extra uncertainty with the R&D data for both the Swedish paper and the printing and publishing industry, since their combined data were divided between these two sectors using a rule of thumb (gross expenditures on R&D were divided between them in the same proportions that net expenditures had). Nevertheless, the results seem to be so convincing and stable that we could put forward the same conclusions as for the paper industry: that the technology flow from outside the industry is more important than own research efforts, and that perhaps some part of those efforts have been wasted, meaning that a higher rate of return could have been obtained by investing in capital goods.

For Finland also the results were fairly similar as for the paper industry. With a 0.1 depreciation rate for R&D, both the constant and the capacity variable were systematically positive and significant, whereas the R&D showed less stability. In this case also lag length 6 seemed to produce a positive and significant coefficient, which should be looked at with the usual cautiousness. Here, as in the case of Sweden, a 0.2 depreciation rate produced fairly similar results, which could be seen as implying a fairly similar knowledge base in both countries. The difference between the two countries is again seen in investing in R&D: In Finland the own research intensity has declined rapidly over the period 1963-83, whereas in Sweden there was a rapid increase. In wiew of the results presented above, the latter has perhaps not been a profitable strategy.

Table 6.
Selected regression results for the printing and publishing industry, 1964-83

Eq. no.	Country	Lag (i)	Depreciation rate	Constant	$\hat{u}$	$\hat{R}_{t-i}$	R^2	D-W
(21)	Fin	6	0.1	1.063	.388	.221	.7440	1.927
				(5.127)	(6.357)	(1.891)		
(22)	Swe	1	0.1	1.408	.352	-.090	.7862	1.761
				(5.144)	(7.540)	(-2.551)		

Note. t statistics in brackets below the coefficients, DW = Durbin-Watson statistic.

CHEMICAL INDUSTRIES

In parts of the chemical industries research intensity is among the highest in manufacturing, and in many firms e.g. in the pharmaceuticals industry it is substantially higher than the manufacturing average. Because of these large investments the productivity effects of these research efforts are very important. For Norway, synergy effects between oil refining and some other chemical industries could a priori be expected because of the oil sector boom since the early 1970's.

However, the results concerning Norway are not very convincing in this respect. The best results were obtained when using the 0.2 depreciation rate for research capital, but with none of the lag lengths ranging from zero to six years did this variable get an even near-significant coefficient. Instead, the constant term was clearly positive and significant in each case (in addition to the capacity utilization variable). Thus, it would seem that what matters for productivity growth in the Norwegian chemical industries is technology flowing from outside sources, plus changes in utilization rates. Of course, this result may be a consequence of dealing with a fairly large aggregate, where possibly opposite developments for different subsectors even each other out, and of the fact that the period studied (1964 to 1983) contains two very different subperiods, especially concerning the oil sector.

For Sweden the results are very much in line with the ones for Norway, although Sweden has to import all of its oil. Looking again at the results based on the 0.2 depreciation rate of R&D capital, the constant term was positive and significant for four different lag lengths (0, 1, 3 and 6 years), but the R&D variable was never significant. In contrast, for Finland the research capital variable had a positive and significant coefficient with depreciation rate 0.2 and lag length six years. Because of the limited number of observations this result merits some cautiousness in making inferences, especially as the Durbin-Watson test statistic for autocorrelatedness is suspectably low. The constant term is again positive and significant for a zero lag, and near-significant for lag lengths of 3 and 4 years.

What can be said, then, is that except possibly for Finland, own R&D does not seem to create positive excess returns in the form of increased productivity in the chemical industries, at least when looking at this broad aggregate. Instead, autonomous technological change coming from other sectors or firms seems to be important in all three countries. These results are to some extent in conflict with the assumption presented in the Introduction that in industries with a high research intensity, own research would be more important than technology acquired from outside sources. However, this may be an example of the interrelatedness of the two main sources of technology: at least part of the knowledge used in the chemical industries may easily be interpreted to be of such a nature that without substantial own research and keeping up-to-date, it would not be possible to use effectively the technological knowledge created by others.

Table 7.
Selected regression results for the chemical industries, 1964-83

Eq. no.	Country	Lag (i)	Depreciation rate	Constant	$\hat{u}$	$\hat{R}_{t-i}$	R^2	D-W
(23)	Fin	0	0.2	1.444 (2.504)	.201 (7.159)	-.072 (-1.061)	.7964	1.972
(24)	Fin	6	0.2	-.310 (-.679)	.201 (9.253)	.137 (2.596)	.8878	1.258
(25)	Swe	3	0.2	2.528 (2.374)	.285 (7.629)	-.190 (-1.310)	.7927	1.984
(26)	Nor	6	0.2	1.166 (2.692)	.262 (9.024)	-.032 (-.417)	.8539	1.513

Note. t statistics in brackets below the coefficients, DW = Durbin-Watson statistic.

NON-METALLIC MINERAL PRODUCTS

Except for a few years in the case of Finland, research intensity has been clearly below the manufacturing average in the non-metallic mineral products industry in all three countries. However, total factor productivity growth was faster in this sector in the first half of the period 1964 to 1983 than the manufacturing average, and in Finland faster also (on average) in the second half of the period. It is not clear, therefore, whether a positive relationship between research efforts and TFP should be seen from the regression results. Earlier results (Vuori 1986) found no evidence of such a relationship for Finland, but some evidence for Sweden.

Again, the regression results are somewhat mixed. For Norway, the "best" results, in terms of fairly well-behaved models, were obtained when using the 0.2 depreciation rate for research capital. In this case the coefficients of the R&D variable were positive and significant with lag lengths 3 and 4 years. In addition, the constant term was significant (or nearly so) with lag lengths 0, 1 and 2 years, but never simultaneously with the research variable. Moreover, the constant was clearly significant but negative with a zero depreciation rate and a three-year lag, and in this case also the R&D variable was highly significant, and the R^2 was higher than for any other equation concerning this industry. Therefore, no firm conclusions as to the role of autonomous technical change can be made on the basis of this analysis.

For Sweden the 0.2 depreciation rate and lag lengths zero and one year produced satisfactory results, with both the constant term and R&D variable positive and significant. The constant was significant for all other lag lengths too, but there were clear indications of autocorrelation of the error terms. The first-mentioned results are also made less attractive by the fact that for a one-year lag and zero depreciation, the R&D variable is positive and significant but the constant term is negative and significant. Thus again, we cannot be too confident of the role of autonomous technical change.

Table 8.
Selected regression results for the non-metallic mineral products industry, 1964-83

Eq. no.	Country	Lag (i)	Depreciation rate	Constant	$\hat{u}$	$\hat{R}_{t-i}$	R^2	D-W
(27)	Fin	0	0.2	1.494 (4.587)	.284 (8.862)	.017 (.932)	.8565	1.380
(28)	Swe	1	0	-2.692 (-2.428)	.413 (9.491)	.845 (3.716)	.8445	1.586
(29)	Swe	1	0.2	.699 (2.392)	.415 (9.159)	.162 (3.426)	.8333	1.485
(30)	Nor	3	0	-2.004 (-2.962)	.423 (11.582)	.377 (3.783)	.8927	2.549

Note. t statistics in brackets below the coefficients, DW = Durbin-Watson statistic.

For Finland, the coefficient of the R&D variable was not significant in any of the versions of the model that were used (with lags ranging from zero to six, and the depreciation rate of R&D capital taking values 0, 0.1 or 0.2). When using the 0.2 depreciation rate the constant term was always positive and significant, but the low values of the Durbin-Watson statistics casts some doubt as to the validity of this model specification in some of these cases.

Thus, it seems that in the non-metallic mineral products industry autonomous technical change flowing from other sources than the firms' own R&D is probably important, although this conclusion has to accompanied with some reservations. In Sweden and Norway own R&D also seems to have a positive excess rate of return, whereas in Finland this does not seem to be the case. The latter example points to the fact that even a relatively rapid increase in research expenditures does not necessarily lead to strong positive effects, although we also have to keep in mind the possibility of misspecification of the model.

BASIC METAL INDUSTRIES

While the basic metal industries were classified as a high-research-intensity sector in the Introduction, research intensity in both Finland and Sweden declined from above-manufacturing-average levels in the beginning of the period studied here to below-average levels in the end of the period. In the latter half of the period studied, productivity performance outperformed at least slightly the manufacturing average in all three countries.

The regressions for Finland produced very meager results. Capacity utilization rates, which normally explain a very high share of the fluctuations in TFP, did not in this case seem to have anything to do with productivity, and thus the R^2's were always very low. The best results were obtained with a zero depreciation rate of R&D capital and a lag length of six years. In this case the coefficient of the R&D variable was positive and significant, but the constant term was negative and significant. While R^2 was clearly higher than for other lag lengths, it was still very low (.19), and in addition the Durbin-Watson statistic fell in the area of possible autocorrelation.

When using a 0.1 depreciation rate for Sweden, the constant term was always positive and clearly significant, but the R&D variable itself never obtained a significant coefficient.

Table 9.
Selected regression results for the basic metal industry, 1964-83

Eq. no.	Country	Lag (i)	Depreciation rate	Constant	$\hat{u}$	$\hat{R}_{t-i}$	R^2	D-W
(31)	Fin	6	0	-5.011 (-1.750)	.002 (.101)	1.236 (1.804)	.1912	1.200
(32)	Swe	3	0.1	1.653 (4.557)	.206 (5.237)	-.174 (-1.191)	.6175	2.530
(33)	Nor	0	0.2	1.190 (3.264)	.193 (6.305)	-.080 (-1.694)	.7233	1.973

Note. t statistics in brackets below the coefficients, DW = Durbin-Watson statistic.

The most convincing results were found for the Norwegian basic metal industries with lag length zero and a 0.2 depreciation rate for R&D capital. Here both the constant term and the capacity variable obtained clearly positive and significant values, and the R&D variable had a negative and near-significant coefficient. The constant was significant also with lag lengths 3 and 4 years.

It seems, then, that for Sweden and Norway autonomous technical change is more important for productivity increases in the basic metal industries than own research efforts. For Finland own research may have been more important, but there is so far not enough evidence for any firm conclusions. Thus, as with the chemical industries, a relatively high research intensity does not necessarily go hand-in-hand with improved productivity. Instead, at least in Sweden and Norway, technology diffusion seems to be an important source of productivity increases.

METAL PRODUCTS AND ENGINEERING

The metal products and engineering industry is the major spender on R&D in all three countries studied here, both absolutely and relatively, especially in the latter half of the period studied. In Finland and Sweden this sector also outperforms the total-manufacturing average of productivity increase, but falls below it in Norway. It is therefore of special interest to have a closer look at the relationship between R&D efforts and TFP in this industry.

The results are somewhat puzzling. For Finland the coefficient for the zero-lag, zero-depreciation R&D variable is non-significant, which differs from the results concerning the period 1964-80 in Vuori (1986), where it was positive and significant. Instead, the coefficient connected with a lag length of 5 years is negative and significant, and in this case also the constant term is positive and significant (although it has a too high value to be plausible). Qualitatively the results are very similar when using the R&D variable with depreciation rates of 0.1 and 0.2 respectively.

For Sweden the situation is somewhat different. For the zero-lag, zero-depreciation case the coefficient of the R&D variable is positive and significant, but the constant is negative and significant. Furthermore, the test statistics point to a clear autocorrelatedness of the error terms. However, when examining the regressions containing the 0.2 depreciation rates, the models are no better or no worse (roughly speaking) in terms of the overall test statistics than in the zero-depreciation case, but the individual coefficients behave differently. The 0.2-depreciation, zero-lag results are fairly similar to the corresponding zero-depreciation ones, except that the constant term is not significant. Instead, the constant term is positive and significant in four cases out of seven different lag lengths. Thus, the results are so ambiguous that no firm conclusions can be made without further analysis.

In Norway the equations containing the zero-depreciation R&D variable yielded no significant coefficients except the capacity variable. Instead, with a 0.2 depreciation rate the constants were positively significant with lag lengths 1, 3 and 6 years, and in the last case the R&D variable was nearly significant but negative. It also turned out, as in the case of the Norwegian wood industry, that the first couple of years contain an outlier, so that when looking only at the period 1967 to 1983, the coefficients of the R&D variable were significant (and negative) with lag lengths 2 and 3 years with the 0.1

depreciation rate, and lag length 3 years with the 0.2 rate, whereas they were non-significant for the period 1964 to 1983. Thus, it seems fairly safe to conclude that the technology contribution which comes from sources outside the industry is important, and the contribution of own research efforts to productivity growth has been negative, meaning that the return to R&D investments has been lower than the return to fixed capital investment.

Table 10.
Selected regression results for the metal products and engineering industry, 1964-83

Eq. no.	Country	Lag (i)	Depreciation rate	Constant	$\hat{u}$	$\hat{R}_{t-i}$	R^2	D-W
(34)	Fin	5	0	6.383 (2.290)	.165 (7.294)	-.397 (-1.732)	.8005	2.350
(35)	Swe	0	0.2	-.039 (-.051)	.284 (9.552)	.239 (2.290)	.8434	.851
(36)	Swe	2	0.2	2.090 (2.318)	.269 (7.974)	-.052 (-.431)	.7974	1.329
(37)	Nor	6	0.2	.884 (2.330)	.149 (4.901)	-.088 (-1.620)	.7263	1.795
(38)	Nor *)	3	0.1	2.387 (2.739)	.175 (6.695)	-.297 (-2.407)	.7701	1.817

Note. t statistics in brackets below the coefficients, DW = Durbin-Watson statistic.
*) Observations 1967-83

What we can conclude, therefore, is that in the metal products and engineering industry in Finland and Norway, the excess returns to R&D seem to have been negative, which is contrary to our expentations. The result may be at least partly due to the clearly above-average spending on this activity, i.e. of diminishing returns to R&D. For Sweden, the results are more ambiguous and need further examination. Technology diffusion seems to be important in all three countries.

OTHER MANUFACTURING

Other manufacturing is a very heterogenous industry, and therefore, it should perhaps not be regarded as an industry at all. However, to have a complete picture of the relationship between research efforts and productivity in all manufacturing industries, we performed the regressions on this sector as well. This sector has mostly shown a clearly below-manufacturing-average research intensity, but above-average productivity growth.

For Finland, the "best" results were obtained with a 0.2 depreciation rate for research capital. In this case, the constant term was always positive, and significant (or nearly so) for lag lengths 1,3,5 and 6 years. The coefficient of the R&D variable was negative and significant with a lag length of 5 years.

For Sweden the variables examined seem to have almost nothing to do with each other, except that with a lag length of three years and zero depreciation of R&D capital, the research variable obtains a positive and significant coefficient (but its value is implausibly high). Instead, the constant term, and more surprisingly, the capacity utilization variable are never significant. These results may partly be due to the heterogeneity of the industry, and also to possible discontinuities in the data. /Wyatt (1983) also noted that the data for this industry was less reliable than the rest./

For Norway, when looking at the regressions based on the 0.2 depreciation rate case, the constant terms are positive but never significant, the utilization variable is highly significant, and with a lag length of 3 years, the R&D variable is near-significant.

Thus very few conclusions may be drawn on the basis of these results. In Finland autonomous technical change may be more important, and in Norway own research may be more important, whereas in Sweden there seems to be some problem with the data.

Table 11.
Selected regression results for other manufacturing, 1964-83

Eq. no.	Country	Lag (i)	Depreciation rate	Constant	$\hat{u}$	$\hat{R}_{t-i}$	R^2	D-W
(39)	Fin	5	0.2	5.256 (3.986)	.374 (8.501)	-.187 (-2.324)	.8307	1.592
(40)	Swe	3	0	-4.512 (-1.239)	-.048 (-.455)	16.977 (1.733)	.1512	1.683
(41)	Nor	3	0.2	.291 (.672)	.403 (11.756)	.146 (1.507)	.8915	1.858

Note. t statistics in brackets below the coefficients, DW = Durbin-Watson statistic.

3. CONCLUSIONS

The regression results which are reported in section 2 vary quite a lot across industries and countries, and are thus difficult to summarize shortly. We have therefore chosen to recall two sets of regression equations, which are both satisfactory when using certain, slightly different criteria for assessing the results.

The first set of equations is recalled in Table 12. For this table only those equations were chosen, where all explanatory variables obtained a significant coefficient, and where the coefficient of determination and the Durbin-Watson statistic did not cause alarm. The constant term was here required to be positive, assuming that the rate of autonomous technological change should be positive. The coefficient of the R&D capital variable was allowed to have either a positive or negative sign, since both have an interpretation: they imply either a positive or negative excess rate of return to R&D efforts. The capacity utilization variable (u) had almost in all cases that we examined a dominant role in explaining fluctuations in total factor productivity, and thus its coefficient was highly significant, and this variable was not actually effective for choosing between the equations.

A striking thing about these equations is that in only two cases (of these ten equations), i.e. in the Finnish paper industry and the printing and publishing industry, is the coefficient of the R&D variable positive, implying a positive excess rate of return. In all other cases the return is negative, implying that too much has been spent on R&D, or that a better return could have been obtained by investing in machinery and equipment (or by reallocating R&D

Table 12.
Summary of the most satisfactory regression equations, 1964-83

Eq. no.	Country	Lag (i)	Depreciation rate	Constant	$\hat{u}$	$\hat{R}_{t-i}$	R^2	D-W
Wood and wood products								
(16)	Nor *)	4	0.1	.345 (1.800)	.262 (5.219)	-.156 (-2.619)	.8007	2.151
Paper and paper products								
(18)	Fin	6	0.1	.391 (2.591)	.228 (13.397)	.375 (1.714)	.9399	1.538
(19)	Swe	0	0.1	2.492 (4.115)	.308 (14.536)	-.260 (-2.847)	.9463	1.344
(20)	Nor	3	0	2.339 (3.749)	.242 (8.717)	-.389 (-2.221)	.8221	2.059
Printing and publishing								
(21)	Fin	6	0.1	1.063 (5.127)	.388 (6.357)	.221 (1.891)	.7440	1.927
(22)	Swe	1	0.1	1.408 (5.144)	.352 (7.540)	-.090 (-2.551)	.7862	1.761
Basic metal industries								
(33)	Nor	0	0.2	1.190 (3.264)	.193 (6.305)	-.080 (-1.694)	.7233	1.973
Metal products and engineering								
(34)	Fin	5	0	6.383 (2.290)	.165 (7.294)	-.397 (-1.732)	.8005	2.350
(38)	Nor *)	3	0.1	2.387 (2.739)	.175 (6.695)	-.297 (-2.407)	.7701	1.817
Other manufacturing								
(39)	Fin	5	0.2	5.256 (3.986)	.374 (8.501)	-.187 (-2.324)	.8307	1.592

Note. t statistics in brackets below the coefficients, DW = Durbin-Watson statistic.
*) Observations 1967-83

differently across industries). Since the coefficients of R are the output elasticities of R&D, a coefficient of e.g. 0.2 means that a 5 per cent increase in research capital yields a one per cent increase in productivity (or output), and a decrease for a negative coefficient.

The size of the constant term ranges between 0.3 and 6.4 per cent, and clearly the largest two of them (those for the Finnish other manufacturing and the metal products and engineering industry) are not plausible. The coefficients of the capacity variable range between 0.16 and 0.39, which are plausible as such (a coefficient of 0.2 implying that a 5 per cent increase in the rate of capacity utilization would improve productivity by 1 per cent). While the coefficients of this variable were very stable across practically each industry (when varying the lag length and the rate of depreciation of the R&D variable), they should not be taken as exact values, since this variable was constructed using a fairly crude method /See Vuori 1988/.

The second set of equations is summarized in Table 13, but only in qualitative terms. The table is partly overlapping with Table 12, since it summarizes also the ten equations of that table, and contains information on another nine equations. Table 13 seeks to present the main results of this study. The "additional" nine equations are considered to be reasonably reliable, so that at least qualitative conclusions can be made on the basis of them, even if less stringent criteria have been used than when selecting the equations of Table 12. Thus, to be selected into the table, it was enough that either the constant or the coefficient of the research capital variable was significant, and that the equation behaved otherwise reasonably well. What we are trying to determine here is then whether technology diffusion, as reflected in the constant term, or own research of the firms, as reflected in the coefficient of $\hat{R}$, or both, are important for the productivity performance of each industry.

The results seem to very much support the small country argument of the Introduction that technology diffusion is highly important for the firms in small countries: the constant term is positive and significant in all cases but three, out of nineteen cases. As to the role of the own research variable, it is much more variable. In five cases there seems to have been a positive excess rate of return, and in seven cases a negative rate. When these results are compared with the preliminary classification of the industries in Table 1 of the Introduction, the assumptions on which it was based are confirmed only to some extent. According to expectations, diffusion seems mostly (with the exception of the food industry) to be important in the industries with low research intensity, and own research mostly not important.

Instead, and more importantly, the industries with high research intensity (chemicals, basic metals, and metal products and engineering) fail to show convincing evidence of the importance of own research, which is contrary to expectations. In some cases the returns to R&D behave differently across countries, and the evidence of a similar technology base is not in general very strong. This may, of course, partly be due to the differing structures of the corresponding industries in the three countries, since fairly broad aggregates are being studied.

In some previous studies the rates of return to R&D have been estimated to be quite high, of the order of 10-20 % or more /See e.g. Wyatt 1983/. The

Table 13.
The importance of technology diffusion (constant term) and own research (coefficient of R): summary of results *).

Industry	Country	Eq. no.	Constant +/-/N	$\hat{R}_{t-i}$ +/-/N
Food, beverages, tob.	Swe	(5)	N	+
	Nor	(6)	N	+
Textiles, clothing etc.	Fin	(7)	+	N
	Swe	(9)	N	+
	Nor	(11)	+	N
Paper and paper products	Fin	(18)	+	+
	Swe	(19)	+	-
	Nor	(20)	+	-
Printing and publishing	Fin	(21)	+	+
	Swe	(22)	+	-
Chemical industries	Fin	(23)	+	N
	Swe	(25)	+	N
	Nor	(26)	+	N
Non-metallic mineral prod.	Fin	(27)	+	N
Basic metal industries	Swe	(32)	+	N
	Nor	(33)	+	-
Metal products and engineer.	Fin	(34)	+	-
	Nor	(38)	+	-
Other manufacturing	Fin	(39)	+	-

*) + stands for a positive and significant coefficient, - for a negative and significant coefficient, and N for a non-significant coefficient.

results of this paper differ also from those in Vuori 1986. According to that earlier study, for the period 1964-80 the rates of return were positive, but low in the chemical industries and the metal products and engineering industry both in Sweden and in Finland, and clearly higher in the wood and wood products industry. Instead, definitive evidence of positive rates of return was not found in this study, although that possibility was not clearly ruled out either.

Thus, on the basis of these results it seems that the returns to R&D have not been as high as has generally been thought. However, since the evidence of the importance of technology diffusion seems to be very strong, the idea of the interrelatedness of own and adopted technology mentioned earlier when discussing the results for the chemical industries seems to deserve further thought. What this means is that without substantial own research, the fruits of research done by others are bound to be useless for a firm, which is not able to adopt advances in technology and adapt them to its own needs. This seems evident especially in the sectors where research intensity is high internationally also. Moreover, since some sectors, and especially the engineering industry, have been found to be important sources for technological advances leading to productivity growth in other sectors /See Geroski 1990/, it is not enough to look at the effects of an industry's own research on its own productivity.

Investing heavily in own R&D may thus be necessary, even if it does not seem to have been highly profitable. In addition, it is possible that some industries create high social rates of return, part of which are overlooked in this kind of study, since the appropriability of research results is often incomplete, and part of the benefits from research results flow to other sectors at a low or zero price. It should also be remembered that several of the equations that we estimated pointed to the possibility of misspecification of the model. Especially the lag structure of the R&D capital variable seems to deserve further research. Therefore, the relationship between research activities and total factor productivity, and that of diffusion and own research should be investigated more thoroughly than has been possible in this paper. In particular, the extent and impact of technology flows between sectors should be studied.

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