ETLA ELINKEINOELÄMÄN TUTKIMUSLAITOS
THE RESEARCH INSTITUTE OF THE FINNISH ECONOMY
Lönnrotinkatu 4 B, 00120 Helsinki 12, Finland, tel. 601322

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Synnöve Vuori

RETURNS TO R & D IN FINNISH AND SWEDISH MANUFACTURING INDUSTRIES, 1964 TO 1980

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1. Introduction[1)]

An increasing amount of effort has been put to analyse the productivity developments of firms and industries after the first oil shock. A considerable amount of studies both in Europe and North America have focused on the reasons for the generally acknowledged productivity slowdown. Broadly speaking, research and dvelopment activities have been established to be one of the major factors affecting total factor productivity growth. Moreover, advancing R & D investments is also considered to be in the interests of society, as technological change affects positively the growth potential of the economy. The question of whether R & D activities should be preferred to other forms of investment has therefore caused an increased interest to be put on examining the effects of these activities.

The purpose of this study is to assess the social rate of return of research and development expenditures in Finland and Sweden on the basis of total factor productivity developments in manufacturing industries. The rate of return is equivalent to the increase in output which is achieved by means of R & D. Most studies dealing with returns to R & D have been made on a cross section basis. This study attempts to throw some light on the question of whether similar results - rather high rates of return - can be obtained on a time series basis. Since the time series for R & D data are so far fairly short, this study should be regarded as of a preliminary character.

In addition to the firms' own research activities, technological change and know-how is cumulated in them also in many other ways. Firms may benefit from learning by doing, acquire better means of production from other firms, make licensing contracts, hire employees with higher qualifications etc. This study, however, deals primarily with the firms' own research. This is because of problems related to the availability of data as well as data management. Total factor productivity is looked upon at the industry or aggregate economy level. The main question adressed in the study is then whether, from the point of view of industries and the economy as a whole, it has been profitable to invest in these activities.

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1) This paper summarizes the main contents of Vuori (1984).

The productivity data covers ten manufacturing industries in Finland and Sweden during almost twenty years. The estimates are carried out separately for each industry. This is based on the notion that technological change and research intensity are more or less industry specific characteristics. An industry is considered to have a specific industrial base which is similar in the corresponding industries in various countries. This means that inter-industry differences are assumed to be bigger than inter-country differences of corresponding industries. While the comparison between Finland and Sweden is made on an industry-by-industry basis, this does not rule out the possibility of different rates of return to research input. In fact we address the question of whether the rates of return are systematically higher in Finland than in Sweden, of which there have been some indications in an earlier study.[1)]

2. Measurement of returns to R & D in previous studies

For some years now, R&D expenditures of firms have been claimed to produce intangible capital stocks analogously with advertising expenditures, since both have long-run effects which tend to decrease over time. Until quite recently, however, returns to research and development have generally not been estimated on the basis of an explicit R&D capital stock measure. Instead, the usual approach has been to use R&D expenditures as such, assuming that depreciation and carryover effects are small enough to be ignored. Some authors have thus claimed that they have in fact used a research capital concept, on the assumption that expenditures on R&D in a certain year equal the change in the stock of R&D capital in that year.

Previous empirical studies with an explicit research capital concept have in general been based on micro data, with either profitability or the market value of the firm as the dependent variable[2)]. While their results may not be directly applicable to industry data and productivity analysis, they very clearly bring forth the fact that the effects of R&D may be distributed over several years.

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1) Wyatt (1983), p. 75-82.

2) See Grabowski and Mueller (1978), Ravenscraft and Scherer (1982), and Hirschey (1982) for details.

Though a research capital concept has commonly been suggested to be used in the analysis of the productivity effects of R&D, this has in practice not been done very frequently because of data problems. In many countries published R&D data so far cover only short periods, e.g. the 1970's and the first years of the 1980's, which for construction of capital stock variables is in general too short. This in part explains why there have been several different ways of handling the data.

The most commonly used model is based on studies by Griliches and others[1)] and is derived from a Cobb-Douglas type value added production function with research capital (R) as an additional factor of production:

$$Q = e^{\lambda t} L^{\beta} K^{(1-\beta)} R^{\alpha}. \tag{1}$$

Constant returns to scale apply to labour and capital input, and λ is the rate of disembodied productivity growth. Total factor productivity (TFP) is defined as

$$F = \frac{Q}{L^{\beta} K^{(1-\beta)}} = Ae^{\lambda t} R^{\alpha}, \tag{2}$$

and differentiation yields its rate of change:

$$f = \hat{Q} - \beta \hat{L} - (1-\beta)\hat{K} = \lambda + \alpha \frac{\dot{R}}{R}. \tag{3}$$

Since this form of the model requires research capital data, it has become standard practice to modify it by assuming that no depreciation is made on research capital, implying that R&D expenditures equal the growth of the R&D capital stock. When in addition the definition of the output elasticity of research capital (α) is inserted into equation (3), we have

$$f = \lambda + \frac{\partial Q}{\partial R} \cdot \frac{\dot{R}}{Q} = \lambda + v \frac{r}{Q}. \tag{4}$$

1) See e.g. Griliches (1980a) and Terleckyj (1980).

This implies that the rate of TFP growth can be divided into 2 components, the autonomous rate of technological change plus research intensity (research expenditures divided by output) multiplied by the marginal productivity of research capital, or in other words the rate of return to research capital.

Equation (3) implies an assumption of a constant output elasticity of research input, and equation (4) correspondingly an assumption of a constant rate of return across observations. Thus in cross section studies, which has been the dominating approach, either of these two parameters has to be assumed constant across industries or firms. Whether this is in accordance with reality is somewhat doubtful. Instead, in time series analysis either of them is assumed constant over time. For industry or economy averages, this may be somewhat more plausible.

Of the few so far existing time series studies on the productivity effects of R&D we would like to mention Griliches and Lichtenberg (1982) and Griliches (1980b). In addition, Branch (1974) has used an R&D variable to explain the development of firms' profits. In all of these studies pooled cross section - time series data have been used. The results of these studies taken together are somewhat inconclusive. According to Griliches and Lichtenberg, using the model specification based on equation (4), i.e. involving the constant marginal productivity assumption, yields better results than the one based on equation (3). The results of Griliches cast some doubt as to the constancy of v throughout a longer period.

3. Specification and interpretation of the models

To permit wider applicability, the models presented in the previous section will now be further developed by replacing the value added Cobb-Douglas production function by a gross output translog function. In addition, a modification of the model is made which is required because of fluctuations in capacity utilization, and the treatment of lags is discussed.

To find an expression corresponding to (3) or (4) above for a translog function with neutral technological change, define the gross output production function y as follows:

$$y = e^{\ln F(X_n)} \cdot g(t) , \qquad (5)$$

where $F(X_n)$ is a translog function and g(t) is a function describing Hicks neutral technological change

$$g(t) = e^{\lambda t} R^{\alpha} . \qquad (6)$$

R represents research capital, and λ is the rate of autonomous technological change as before. F(X) is in the form of a factor requirements function with three inputs: capital X_K, labour X_L, and material inputs X_M.

With certain restrictions on the parameters a and b this function provides a second-order approximation to an arbitrary twice differentiable function of (X_n), which is linearly homogenous with respect to the inputs[1]. It is thus considerably more flexible than the Cobb-Douglas function which has quite commonly been used but is only a first-order approximation.

From (5) it follows that

$$d \ln y - d \ln F(X_n) = d \ln g(t) , \qquad (7)$$

where $d \ln F(X_n)$ is a Törnqvist-type input index $\Sigma w_n \hat{X}_n$, where the logarithmic differences of each input $\hat{X}_n$ (n = K,L,M) are weighted by the mean of the current and previous periods' value shares[2]. Thus we have for the logarithmic differences of total factor productivity f, when definition (6) is taken into account, the expression

$$f = \hat{y} - \Sigma w_n \hat{X}_n = \lambda + \alpha \hat{R} , \qquad (8)$$

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1) See Diewert (1980), p. 487-90.

2) Diewert (1980), p. 445 and 490-91.

which corresponds to equation (3) above. The empirical analysis in this study is based on TFP differences calculated according to equation (8).

Since most studies on the relationship between TFP and R&D have used cross section data, in general averages over several years, the effects of fluctuations in capacity utilization on productivity have not been much discussed let alone explicitly taken into account in this context[1]. In time series analysis, however, it is clear that these fluctuations should be given some attention.

The framework presented above assumes perfect competition in input markets and thus by definition excludes underutilization of capacity, and changes in TFP should only reflect the rate of technological change. This discrepancy between theory and reality has not yet been solved satisfactorily, and so there is no generally approved method of taking utilization changes into account. In the following, a simple approach is proposed to be used as a first approximation. In this way we hope to get at least a rough idea of the relative importance of research inputs and utilization rates respectively as determinants of observed TFP.

Define potential TFP changes corresponding to full capacity utilization

$$f^P = Q^P - \Sigma w_i \hat{x}_i \ , \qquad (9)$$

where Q^P is the full employment output level and $\Sigma\ w_i \hat{x}_i$ is the corresponding weighted use of inputs. Actual output, which is produced with the same input combination is defined as

$$Q = uQ^P \ , \qquad (10)$$

where u is the rate of capacity utilization. With $u < 1$, inputs are not used effectively. In addition to under-utilization of capital, this definition includes also the assumption that labour input adjusts slowly or not at all to fluctuations in final demand.

1) See, however, the discussions in Gollop and Jorgenson (1980), p. 111-12 and Griliches and Lichtenberg (1982), p. 16.

From (10) it follows that

$$\hat{Q} = \hat{u} + \hat{Q}^P , \tag{11}$$

and with (9) we have

$$\hat{Q} - \Sigma w_i \hat{X}_i = f = f^P + \hat{u} . \tag{12}$$

In other words, the change in below full capacity productivity equals the sum of the changes in full capacity productivity and utilization.

The model derived previously, in which research intensity r/Q explains changes in total factor productivity (equation (4)) is on the full capacity level of the form

$$f^P = a + b \frac{r}{Q^P} . \tag{13}$$

From (12) it then follows that below full capacity

$$f = a + b \frac{r}{Q} u + \hat{u} . \tag{14}$$

Thus the change in capacity utilization is included in the model as a separate explanatory variable, and in addition research intensity is corrected for cyclical variations by multiplying it by the level of capacity utilization. This seems to be relevant since with r relatively small the fluctuations in output strongly affect this ratio, so that the fluctuations in research input would not adequately be reflected in it without this correction.

Since the assumption made previously of rigid labour input is not fully realistic but instead in practice labour input adjusts at least partly to change in demand, this fact should also be taken into account in equation (12). Assuming that definitions (9) and (10) hold but defining actual output to be produced with inputs X_i^T we have for actual changes in TFP

$$f = \hat{Q} - \Sigma w_i^T \hat{X}_i^T , \tag{15}$$

where the w_i^T:s are observed value shares of the respective inputs. Then (12) may be written as

$$f = f^P + \hat{u} - (\Sigma\, w_i^T\, \hat{X}_i^T - \Sigma\, w_i\, \hat{X}_i). \qquad (16)$$

Since the expression in brackets, the difference between the weighted observed and full capacity input changes cannot be calculated, it has to be approximated by some assumption. We therefore make the intuitively appealing assumption that the expression in brackets is a function proportional to the rate of utilization, or gu. Equation (14) then becomes

$$f = a + b\,\frac{r}{Q}\,u + (1 - g)\hat{u}\ . \qquad (17)$$

With g = 0 labour input does not adjust at all and equation (14) holds.

Analogously the model version (3) presented above, in which TFP changes are explained by changes in the research capital stock is at full capacity

$$f^P = a + c\hat{R}\ , \qquad (18)$$

from which it follows on the basis of what was stated above that

$$f = a + c\hat{R} + (1-g)\hat{u}\ . \qquad (19)$$

Since comparable industry utilization time series for Finland and Sweden were not available, we constructed such series by using a very simple procedure, the so called Panic procedure.[1)] It is based on the assumption of linear trend growth of the ratio of potential output to capital stock. This procedure is a fairly crude one and does not work quite satisfactorily in all industries, but we believe that the resulting series reflect fluctuations in utilization to such an extent that they may be used for this analysis, where the main interest is in any case in the effects of research input.

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1) See e.g. Christiano (1981), p. 152-4.

Previous research has supported the view that the gestation periods of research inputs may be quite long. The studies containing attempts to explain the development of some performance variable by cumulative research expenditures have generally applied geometric (Koyck-type) or binomial lag distribution structures. According to some results[1) the lag distribution of research input is roughly bell-shaped and the average lag length is from four to six years. In our study the length of the time series available (17 years for TFP and even shorter for research input) restricts the possibilities for analysing the lag structures in the relationship to be studied. As the lag effects are clearly important we in any case try to get a rough idea of the length of the lags.

We tried both geometric lags and Almon polynomials on model version (17), but the results were at best ambiguous. We reached the conclusion that the combination of this model specification and these lag structures were not consistent with our data, probably partially because of the shortness of the time series. For this reason we concentrated our main efforts on model version (19).[2) In this case there is an inherent lag structure in the reserach capital variable, since it contains the research inputs of several subsequent periods. In the case of non-zero depreciation of research capital, this is equivalent to using a geometric lag structure. Thus the model must not contain the research capital variable more than once, lest the research inputs of the various periods should be included several times. We then experimented with the model using different lag lengths trying to find the lengths best in accordance with the data. This model thus was of the form

$$f_t = a + b\hat{R}_{t-i} + c\hat{u}_t \quad . \qquad (20)$$

We hypothesized at the outset that the lag structures of corresponding industries in Finland and Sweden should be equal.

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1) Ravenscraft and Scherer (1982), p. 619.

2) In contrast, as pointed out in section 2, Griliches and Lichtenberg (1982) obtained better results with the research intensity model. Their analysis differs from this study in several respects, however.

The interpretation of the model deserves a few comments. In principle this is simple and straightforward, but several measurement problems complicate the interpretation of empirical results. In one of its two basic forms the model was presented above as

$$f = \lambda + v \frac{r}{Q} , \tag{4}$$

according to which the growth in TFP consists of two additive factors. Of these, λ is considered to be exogenous or autonomous from the point of view of the firms' own activities, or the disembodied rate of technological change. This factor then includes general technological changes as well as the use of the results of research done in other enterprises and industries. Because of measurement problems, quality changes of inputs cannot in general be adequately taken into account in productivity calculations, and thus λ absorbs also a part of these effects.

The second term, the marginal productivity of research capital (v) is interpreted as the gross rate of return to research capital, in micro analysis as the private rate and in industry analysis as the social rate of return. This rate of return is also distorted because of measurement problems. This has not adequately been noted in the relevant literature except for in a few cases. Schankerman has formally derived the size of the bias related to the standard calculation procedure.[1] Because of this bias, v is an excess rate of return, which is on top of normal factor incomes. The measurement problems are caused by the fact that in general research input cannot be separated from labour and capital input but are instead included in these also. Research labour and capital input are then included twice, and thus v is an excess rate.

4. Empirical results

As TFP variables we use Wyatt's (1983) industry series for Sweden and Finland. The data is based on National Accounts and covers ten manufacturing industries in 1964-80. According to Wyatt's results, TFP growth slowed down in most manufacturing industries both in Finland

1) See Schankerman (1981), Griliches (1980a), and Griliches and Lichtenberg (1982).

and in Sweden after the beginning of the 1970's. This is in accordance with experience in other industrialized countries. Before this turning point, growth was in general faster in Sweden, but thereafter in Finland.

As R & D variables we use the gross expenditures on R & D of the respective industries from OECD research statistics and national sources. As is typical with R & D statistics, there are several problems with this data. The most serious one is the lack of long time series, which ideally would be needed for construction of research capital variables. We therefore had to make some assumptions as to the long-term development of research expenditures. Although the levels of the research capital variables which we constructed may deviate somewhat from ones which could be obtained with more accurate data, we believe that the results based on the changes of these variables would not be essentially different, at least qualitatively. Another problem is the lack of a suitable price deflator for R & D expenditures. We have sticked to the usual practice of using the GDP deflators with the hope that they are not too different from more relevant indices.

For constructing the research capital series, we assumed the trend growth rate of constant-price research expenditures in the 1960's and 1970's to have prevailed in the earlier period also. We then have for research capital in each industry in the "base year" 1960[1)]

$$R_{1960} = r_{1960} \left(\frac{1+\gamma}{\gamma+\delta}\right) , \qquad (22)$$

where r_{1960} is research expenditure (in constant prices) in 1960, γ is the trend growth rate of research expenditures, and   is the depreciation rate of research capital. As the depreciation rate we used mainly zero, which has been most commonly used in the relevant literature, but we also constructed the R & D capital series based on 10 and 20 per cent depreciation rates respectively, to make some experiments as to the sensitivity of the results to the depreciation rate.

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1) See e.g. Hirschey (1982), p. 378-9.

We concentrated our estimation efforts on the model version where the changes in TFP were explained by the changes in the research capital stock. As there was no clear idea of how long the lags are, we made experiments with the model using different lag lengths. As noted above, each model contained the research capital variable only once (lagged or unlagged). Estimations were also made using changes in research capital based on the various depreciation assumptions (0, 10 or 20 per cent).

Appendix Table 1 contains regression results for the ten manufacturing industries of the two countries. These results were chosen on the basis of the behaviour of the research capital variable, using basically the highest t value associated with its coefficient as the choice criterion. In the majority of the chosen models the coefficient or $\hat{R}$ was positive and significant at the 5 or 10 per cent level. In several industries $\hat{R}$ based on non-zero depreciation yielded a more significant coefficient than zero depreciation, but for the majority of industries the effect of the depreciation rate was fairly small.

The results presented in the table should be interpreted with caution. The estimation experiments provided additional support to the conclusion drawn from the model version using research intensity that the coefficients are fairly unstable. In addition the most significant lags were in several industries fairly long, 5-6 years. Such a length is plausible as such e.g. in the chemical industry, but with time series of only 17 years the results cannot be considered quite reliable. It should be noted also that the in most cases rather high coefficients of determination are to a great extent due to the dominating effect of the capacity utilization variable.

The coefficients of $\hat{R}$ presented in Appendix Table 1, which are interpreted as output elasticities of research input, vary substantially between industries and in many cases also between the same industry in Finland and Sweden. Since output is here defined in gross values, it may be expected that also the average productivity of research input varies greatly. This may be due to differing structures of corresponding industries. Thus the rates of rerturn to research capital may behave quite differently from the elasticity estimates. To verify this we calculated the corresponding rates of return, which are presented in Appendix Table 2.

The variation of the rates of return seems to be much smaller than the variation of the output elasticities. The majority of the rates of return lies between one and 14 per cent. Clearly higher rates are found in printing and publishing in Finland (22 %) and in manufacture of wood and wood products in Sweden (68 %). In Swedish paper and printing and publishing industries the elasticities and thus also the rates of return are negative. This is quite possible in view of the interpretation presented above that the rate is an excess rate of return. Another explanation may, however, be that there was additional uncertainty as to the allocation of R & D between these industries. In several industries the rates of return seem to be fairly similar in Finland and in Sweden. Although the rates of return vary quite a lot, the results do not support Wyatt's (1983) conclusion referred to above that the rates of return would be systematically higher in Finland than in Sweden. Since several of the coefficients of $\hat{R}$ in Appendix Table 1 were significant only at the 10 per cent level and some of them non-significant, these rates of return should be treated as of an indicative character only.

We made a more systematic analysis of the behaviour of the coefficients of $\hat{R}$ with varying lag lengths using research capital variables based on zero depreciation. On the basis of this analysis, the output elasticies of research capital were in many industries clearly higher in Sweden than in Finland. The elasticities are on average fairly unstable and vary both in the positive and negative range. The instability seems to be greater in Finnish than in Swedish industries.

On the basis of these results it is difficult to conclude that there would be a clear and uniform relationship between research input and total factor productivity in all industries. The relationship in a certain Finnish industry also seems to differ from the corresponding Swedish one both as to the size of the elasticity and lag length. The most uniform results concerned the wood and wood products industries, chemical industries and metal products and engineering industries of these countries. In these industries elasticities associated with the same lag length with relatively high positive t values were found. We thus estimated for these industries seemingly unrelated regression equations (SURE) on the basis of the hypothesis that the relationship being studied is similar in the two countries. This procedure improves the efficiency of estimation, if the error terms of the equations are correlated.[1)] Since the number of observations is here fairly low, the simultaneous estimation of two equations improves the reliability of the results. At the same time we can test the validity of restrictions between the equations, in this case the equality of the output elasticity of research input in Finland and Sweden.

The estimation results are presented in Table 1. For easy comparison the table contains also the corresponding standard regression results from separate equations. For the SURE estimations the table contains in addition to R^2 corrected for degrees of freedom, the coefficient of determination proposed by McElroy. The third pair of equations for each industry contains a restriction concerning the equality of the elasticities. The F statistic measuring the validity of this restriction is also presented in the table.[2)]

For all three industries the elasticity estimates remained approximately the same when using SURE, but their significance increased considerably. In the wood and wood products industry the elasticity estimate is in Finland 0.04 and in Sweden 1.55, but because of a large variance the hypothesis concerning the equality of the coefficients is rejected only marginally at the 5 per cent risk level. In the chemical industry the hypothesis on the equality of elasticity remains valid, but in the metal products and engineering industries it is rejected. In the former industry the estimates were about 0.3 in Finland and about 1.4 in Sweden, and in the latter industry 0.4 in Finland and 1.2 in Sweden. E.g. an elasticity of 0.3 implies that a one per cent increase in research capital stock increases total factor productivity and thus output by 0.3 per cent.

In Table 2 the rates of return calculated from the output elasticities of research input in these three industries are presented both for the zero and the 20 per cent depreciation case. Except for the Swedish wood and wood products industry the size of the depreciation rate does not seem to influence very much the rate of return. In the chemical and the metal products and engineering industries the rates of return are in both countries fairly low, 2–5.5 per cent. This is thus the excess return

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1) See Harvey (1981), p. 67.

2) The test statistics are presented in McElroy (1977).

Table 1

OLS and Seemingly Unrelated Regression Equations (SURE) results for selected industries

The model: $y_t = a + b_i \hat{R}_{t-i} + c\hat{u}_t$

Industry	Method	Country	Lag (i)	a	b_i	c	$\bar{R}^2$	D-W	Depreciation if non-zero, %
33	OLS	Fin	2	0.034 (0.09)	0.040 (1.82)	0.217 (11.0)	0.895	1.32	20
		Swe	2	-4.62 (1.77)	1.55 (2.12)	0.344 (5.86)	0.698	1.46	
	SURE 1)	Fin	2	0.036 (0.09)	0.040 (2.72)	0.217 (16.6)	0.910	1.32	20
	Rm^2= 0.865	Swe	2	-4.55 (2.49)	1.53 (3.14)	0.344 (8.79)	0.741	1.45	
	SURE 2)	Fin	2	0.017 (0.04)	0.041 (2.81)	0.217 (16.6)	0.910	1.31	20
	F(1,25)=4.33 Rm^2= 0.842	Swe	2	0.704 (1.14)	0.041 (2.81)	0.301 (8.25)	0.644	0.84	
35	OLS	Fin	5	-1.64 (0.78)	0.278 (1.13)	0.207 (6.25)	0.788	2.05	
		Swe	5	-10.1 (1.71)	1.54 (1.90)	0.269 (5.47)	0.807	2.22	
	SURE 1)	Fin	5	-1.72 (1.22)	0.288 (1.81)	0.204 (9.51)	0.827	2.09	
	Rm^2= 0.826	Swe	5	-9.06 (2.35)	1.40 (2.65)	0.268 (8.40)	0.842	2.15	
	SURE 2)	Fin	5	-2.60 (1.94)	0.391 (2.61)	0.204 (9.47)	0.823	2.20	
	F(1,19)=1.80 Rm^2= 0.81	Swe	5	-1.74 (1.49)	0.391 (2.61)	0.291 (9.77)	0.786	1.78	
38	OLS	Fin	0	-3.28 (1.23)	0.364 (1.77)	0.160 (6.64)	0.748	2.03	
		Swe	0	-2.08 (3.47)	1.20 (4.31)	0.261 (9.89)	0.865	1.57	
	SURE 1)	Fin	0	-3.41 (1.91)	0.375 (2.74)	0.163 (10.2)	0.782	2.04	
	Rm^2= 0.848	Swe	0	-2.01 (4.32)	1.17 (6.31)	0.262 (14.9)	0.883	1.61	
	SURE 2)	Fin	0	-6.94 (4.66)	0.649 (5.75)	0.163 (10.2)	0.759	2.28	
	F(1,27)=5.86 Rm^2= 0.814	Swe	0	-0.92 (2.63)	0.649 (5.75)	0.243 (14.5)	0.772	2.35	

33 = wood and wood products
35 = chemical industries
38 = metal products and engineering

t statistics in brackets below the coefficients, $\bar{R}^2$ = R^2 corrected for degrees of freedom, Rm^2 = McElroy's measure of goodness of fit, DW = Durbin - Watson statistic

1) No restrictions between coefficients. 2) Restriction between equations: coefficient of $\hat{R}_{t-i}$ = corresponding coefficient in Sweden. 3) The equation for Sweden with Cochrane - Orcutt adjustment.

Table 2

Rates of return to research capital (v) based on output elasticity estimates of research input (b)

(i) Depreciation rate of research capital = 0

Industry	b		v	
	Finland	Sweden	Finland	Sweden
33 Wood and wood products	0.09	1.53	12.2	66.2
35 Chemical industries	0.29	1.40	2.76	5.46
38 Metal products and engineering	0.38	1.17	3.25	3.05

(ii) Depreciation rate of research capital = 0.2

Industry	b		v	
	Finland	Sweden	Finland	Sweden
33 Wood and wood products	0.04	0.15	13.3	42.4
35 Chemical industries	0.078	0.35	2.51	5.08
38 Metal products and engineering	0.13	0.20	2.83	1.85

obtained in the form of additional output when such an amount of funds is allocated to R & D which corresponds to one per cent of the value of output. In the Finnish wood and wood products industry the rate of return was 12-13 per cent and in Sweden 42-66 per cent depending on the size of the depreciation rate.

These figures lie on both sides of e.g. the rate of return to research capital in total manufacturing of 20-30 per cent estimated by Wyatt[1]. Thus the dispersion of rates of return seems to be wide between industries, but on average they are clearly below the figures of Wyatt. According to our results the rate of return would be clearly higher in Sweden than in Finland in the wood industry and to some extent also in the chemical industry. In the metal products and engineering industry the rate of return seems to be lower in Sweden. It should be noted, however, that all the elasticity estimates of Table 2 were not significant. Thus any final conclusions as to the size of the rates of return cannot be drawn on the basis of these results.

As can be seen from Appendix Table 1, the change in capacity utilization explains a considerable part of the variation in TFP. The coefficient of this variable is positive and very significant in most industries. The size of significant coefficients varies in general in the range 0.15-0.4. According to what was stated above in section 3, a coefficient of unity would correspond to perfect rigidity of labour input with respect to cyclical variations. The estimation results imply that this assumption is not valid. On the basis of the estimated coefficients a 5 per cent increase in capacity utilization would increase TFP by 0.75-2 per cent. While the size of the impact is plausible as such, the values of the coefficients should be interpreted with caution also because of the additional defects associated with the utilization variables.

According to theory the constant term in the model should represent autonomous technological change in the industry, and thus it should be positive. For several industries, however, the constant is negative,

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1) Wyatt (1983), p. 75-82. Wyatt's results are roughly in line with previous results on US data by e.g. Griliches (1980a) and Terleckyj (1980).

and in three cases also significant at the 5 per cent level. This would imply that without the own efforts of the industry the development of TFP would be declining. As a long-term average this is not plausible, and the probable explanation lies in the measurement problems associated with the variables. Another possible explanation could be non-neutral technological change.

To sum up, the relationship between industry research input and TFP was not found to be very strong in time series data. There were clear indications of such a relationship, but evidently the data was too small to provide conclusive support. In several industries the lags seemed to be fairly long. The variations in capacity utilization explained a considerable part of the variations in TFP.

5. Conclusions

The study analyses the effects of R & D on the development of total factor productivity (TFP) by industries in Finland and Sweden on a time series basis. The analysis is based on a model using research capital as a central concept, and two related versions are examined. The model version using the rate of change of research capital as a determinant of changes in TFP produced more encouraging results than the one containing research intensity.

In the theoretical model the research input variable is the only determinant of changes in TFP. In empirical time series analysis, however, changes in capital utilization have to be taken into account. In fact the change in utilization proves to be a highly significant determinant in almost every industry being studied.

So far industry-specific time series analyses of the relationship between research input and TFP have been practically non-existent. In this study we could not find very strong support for the earlier results from cross section studies, according to which the rates of return to research and development are very high. There were clear indications of a positive relationship in nearly all industries, but the limited size of the data restricted the possibilities for conclusions. In several cases the lags seemed to be fairly long and in addition in many cases different in the corresponding industries in Sweden and Finland. This question deserves further examination in later studies.

Among the industries for which more thorough estimations of the output elasticities of research input were made, the rate of return to research capital seemed to be fairly low in the chemical industries and the metal product and engineering industries, and also considerably lower than in previous cross section studies. In contrast, the rate of return was very high in Swedish wood and wood products industry, and in Finland too it was clearly higher than in the two earlier-mentioned industries. The rate of depreciation used for research capital seemed to influence the rate of return significantly only when the rate of return was especially high.

It should be remembered that the rates of return are interpreted as excess rates, on top of factor incomes. Thus their positivity implies that the returns to R & D exceed the returns to fixed capital. While it was not possible to obtain reliable estimates of rates of return for all industries, it is possible that the rates vary considerably between industries. Although there were differences between corresponding Finnish and Swedish industries, the industry-specific rates of return do not seem to be systematically higher in either country.

The period analysed contains two very different parts. These are separated by the first oil crisis, after which strong changes in relative prices have caused substantial structural changes in production. This may be an explanation for the fact that no strong conclusions could be drawn as to the relationship being studied. This may also be caused by simultaneity problems: a favourable productivity development could also increase the allocation of funds to R & D. In any case it is clear that this area deserves further research in the near future.

REFERENCES

CHRISTIANO, L.J. (1981), A Survey of Measures of Capacity Utilization. IMF Staff Papers, Vol. 28, Nr. 1, March 1981.

DIEWERT, W.E. (1980), Aggregation Problems in the Measurement of Capital, in Usher, D. (ed.), The Measurement of Capital.NBER Studies in Income and Wealth, Volume 45, The University of Chicago Press, p. 433-528.

GOLLOP, F.M. and JORGENSON D.W. (1980), U.S. Productivity Growth by Industry, 1947-73, in Kendrick and Vaccara (1980), p. 17-124.

GRABOWSKI, H.G. and MUELLER, D.C. (1978), Industrial Research and Development, Intangible Capital Stocks, and Firm Profit Rates, Bell Journal of Economics 9, Autumn 1978.

GRILICHES, Z. (1980a), Returns to Research and Development Expenditures in the Private Sector, in Kendrick and Vaccara (1980), p. 419-454.

GRILICHES, Z. (1980b), R & D and the Productivity Slowdown, American Economic Review, Papers and Proceedings, Vol. 70, No. 2, May 1980.

GRILICHES, Z. and LICHTENBERG, F. (1982), R & D and Productivity at the Industry Level: Is There Still a Relationship? National Bureau of Economic Research, Working Paper No. 850.

HARVEY, A.C. (1981), The Econometric Analysis of Time Series, Philip Allan.

HIRSCHEY, M. (1982), Intangible Capital Aspects of Advertising and R & D Expenditures, Journal of Industrial Economics, Vol. XXX, No. 4, June 1982.

KENDRICK, J.W. and VACCARA, B.N. (eds.) (1980), New Developments in Productivity Measurement and Analysis. NBER Studies in Income and Wealth, Volume 44, The University of Chicago Press.

McELROY, M.B. (1977), Goodness of Fit for Seemingly Unrelated Regressions, Journal of Econometrics, Vol. 6, No. 3, November 1977.

RAVENSCRAFT, D. and SCHERER, F.M. (1982), The Lag Structure of Returns to Research and Development. Applied Economics, Vol. 14, No. 6, December 1982.

SCHANKERMAN, M. (1981), The Effects of Double-Counting and Expensing on the Measured Returns to R & D, Review of Economics and Statistics, Vol. LXIII, No. 3, August 1981.

TERLECKYJ, N.E. (1980), Direct and Indirect Effects of Industrial Research and Development on the Productivity Growth of Industries, in Kendrick and Vaccara (1980), p. 359-386.

VUORI, S. (1984), Kokonaistuottavuus ja tutkimus- ja kehitystoiminnan tuottoaste Suomen ja Ruotsin teollisuustoimialoilla v. 1964-80. The Research Institute of the Finnish Economy (ETLA), Series C, No. 32.

WYATT, G.J. (1983), Multifactor Productivity Change in Finnish and Swedish Industries, 1960 to 1980, The Research Institute of the Finnish Economy (ETLA), Series B, No. 38, Helsinki.

Appendix Table 1

Regression results[1)] for manufacturing industries

The model: $y_t = a + b_i\hat{R}_{t-i} + c\hat{u}_t$

Industry	Country	Lag (i)	Depreciation %	a	b_i	c	R^2	D-W
31 Food, beverages and tobacco	Fin	5	0	-1.81 (1.80)	0.281 (2.13)	0.151 (7.05)	0.873	2.41
	Swe	1	20	-0.314 (1.33)	0.056 (2.16)	0.098 (1.76)	0.464	1.55
32 Textile, wearing apparel and leather	Fin[2)]	3	0	0.654 (1.58)	0.087 (1.68)	0.176 (7.71)	0.761	1.60
	Swe	2	0	-2.68 (1.21)	1.24 (1.96)	0.225 (2.57)	0.497	1.48
33 Wood and wood products	Fin	2	20	0.034 (0.09)	0.040 (1.81)	0.217 (11.02)	0.910	1.32
	Swe	1	0	-4.62 (2.14)	1.56 (2.57)	0.315 (6.28)	0.767	1.25
341 Paper and paper products	Fin	2	10	0.222 (1.12)	0.275 (1.06)	0.259 (11.6)	0.919	1.42
	Swe	3	20	1.43 (3.55)	-0.114 (1.97)	0.338 (11.1)	0.928	1.38
342 Printing and publishing	Fin	3	0	0.165 (0.14)	0.210 (0.66)	0.365 (5.70)	0.761	2.02
	Swe	0	0	2.38 (3.72)	-0.324 (2.36)	0.375 (6.60)	0.761	2.11
35 Chemical industries	Fin	6	20	-0.626 (1.16)	0.147 (2.66)	0.184 (6.19)	0.878	2.10
	Swe	5	0	-10.1 (1.70)	1.54 (1.89)	0.269 (5.47)	0.842	2.22
36 Non-metallic mineral products	Fin	0	20	1.70 (5.19)	0.006 (0.42)	0.290 (8.97)	0.878	1.39
	Swe	1	10	0.219 (0.38)	0.260 (2.61)	0.460 (5.95)	0.741	1.58
37 Basic metal industries	Fin	6	0	-5.76 (2.19)	1.30 (2.14)	0.031 (1.29)	0.447	1.89
	Swe	2	20	1.20 (2.73)	0.080 (0.89)	0.155 (2.77)	0.471	2.26
38 Metal products and engineering	Fin	0	0	-3.31 (1.25)	0.364 (1.78)	0.159 (6.66)	0.770	1.92
	Swe[2)]	0	0	-7.88 (3.47)	1.20 (4.31)	0.260 (9.89)	0.792	1.57
39 Other manufacturing	Fin	0	20	0.627 (0.50)	0.092 (1.34)	0.344 (8.03)	0.827	2.05
	Swe	3	0	-7.59 (1.55)	21.7 (1.71)	-0.168 (1.13)	0.241	1.76

1) The models were chosen on the basis of the highest t values associated with the coefficients of $\hat{R}$.

2) Cochrane-Orcutt adjustment

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

Appendix Table 2

Rates of return to research capital ($v = b \cdot Q/R$)
elasticity estimates of research input (b)

Industry	Country	Lag (i)	Depreciation %	b	Q/R	v
31 Food, beverages and tobacco	Fin	5	0	0.281	46.7	13.1
	Swe	1	20	0.056	75.0	4.2
32 Textile, wearing apparel and leather	Fin	3	0	0.087	53.3	4.6
	Swe	2	0	1.24	10.8	13.4
33 Wood and wood products	Fin	2	20	0.040	312.5	12.5
	Swe	1	0	1.56	43.4	67.7
341 Paper and paper products	Fin	2	10	0.275	23.9	6.6
	Swe	3	20	-0.114	38.7	-4.4
342 Printing and publishing	Fin	3	0	0.210	106.7	22.4
	Swe	0	0	-0.324	94.0	-30.5
35 Chemical industries	Fin	6	20	0.147	32.2	4.7
	Swe	5	0	1.54	3.90	6.0
36 Non-metallic mineral products	Fin	0	20	0.006	80.1	0.48
	Swe	1	10	0.260	16.2	4.2
37 Basic metal industries	Fin	6	0	1.30	6.84	8.9
	Swe	2	20	0.080	14.4	1.2
38 Metal products and engineering	Fin	0	0	0.364	8.54	3.1
	Swe	0	0	1.20	2.61	3.1
39 Other manufacturing	Fin	0	20	0.092	112.4	10.3
	Swe	3	0	21.7	0.47	10.2

ELINKEINOELÄMÄN TUTKIMUSLAITOS (ETLA)
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Lönnrotinkatu 4 B, SF-00120 HELSINKI Puh./Tel. (90) 601 322

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