SNF-REPORT NO. 32/01

Real cost reductions in Norwegian manufacturing and service industries

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SNF project No. 7790
"Immaterielle ressurser som kilde til verdiskapning"

This project is financed by the Research Council of Norway.

FOUNDATION FOR RESEARCH IN ECONOMICS AND BUSINESS ADMINISTRATION
BERGEN, AUGUST 2001

ISBN 82-491-0153-7
ISSN 0803-4036

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Abstract

This paper benefits from a unique Norwegian data base of financial statements utilized to estimate annual productivity scores by a dual measure of technological change. We calculate real cost reductions and find that companies operate their activities in a cost efficient way. We provide evidence that intangible assets contribute more to increasing productivity than tangible assets. Service industry companies, having a substantial proportion of intangibles, score significantly higher on our measure of technological change than those in the manufacturing industry. Furthermore, technological change in more knowledge-based companies, measured by labor intensity, correlates significantly positive with our productivity measure.

Keywords: Technological change; Real cost reductions; Intangibles

JEL classification: O47

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Sammendrag på norsk

Økt produktivitet er typisk en konsekvens av å implementere nye produksjonsmetoder og/eller nye organisasjons-, markedsførings- og styringssystemer i en bedrift. I den senere tid har fokus i større grad vært rettet mot immaterielle aktivas betydning for teknologisk forbedring. Goldfinger (1997) hevder at kilden til økonomisk verdiskapning ikke lenger er produksjon av materielle, fysiske varer, men snarere å skape og få immaterielle, ikke-fysiske enheter til å fungere. Følgelig kan en forvente at sektorer med en stor andel av immaterielle aktiva viser større produktivitetsforbedringer enn sektorer med en liten andel.

Dette arbeidet forsøker å kaste lys over denne problemstillingen ved å estimere produktivitetsforbedringer for et meget stort utvalg norske selskaper for perioden 1991 til 1997. Vi har tilgang til en svært omfattende database, som inneholder regnskapsdata fra Brønnøysundregistrene for alle norske selskaper. Vi benytter et dualt mål på teknologisk endring, hvilket betyr at grunnlaget for beregningene er reduksjon i realverdien av de totale kostnadene.

Vi finner at norske selskaper har fungert kostnadseffektivt i analyseperioden. Industriselskapene kan vise til en gjennomsnittlig årlig produktivitetsforbedring på ca. 0,35%, mens selskapene i servicesektoren kan vise til en forbedring på ca. 0,73%. Denne forskjellen er klart statistisk signifikant. Siden servicesektoren har et større innslag av immaterielle aktiva, støtter denne observasjonen oppfatningen om disse aktivenes økte betydning for teknologisk fremgang. Innenfor industrisektoren finner vi at produktivitetsforbedringen har vært ikke-signifikant i konkurranseskjermet del (matvareproduksjon) og signifikant negativ for kategorien maskiner og utstyr. Gitt at immaterielle aktiva i nyere tid betyr mer for produktiviteten enn materielle, er det rimelig å anta at den teknologiske forbedringen er høyere i sterkt kunnskapsbaserte sektorer av økonomien. Vi finner støtte for dette synet ved at selskapenes grad av arbeidsintensitivitet korrelerer signifikant positivt med vårt produktivitetsmål.

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1. Introduction

Technological change is the advance of technology, which may take the form of new methods of producing existing products as well as new techniques of organization, marketing and management. Innovativeness is commonly assumed to be one of the driving forces behind productivity growth, and increased knowledge is commonly assumed to be one of the driving forces behind innovativeness. We observe an extensive heterogeneity in the firms' productivity that cannot be explained by variation in size, capital intensity or type of production. The importance of an increased dependency of intangible resources as a source for recent positive trends in productivity and competitiveness is also recognized. These assets include technology, human capital, organizational flexibility, marketing, software and external network. According to Goldfinger (1997), who presents an interpretation of major changes affecting modern economy, the major force shaping the economy is the shift to the intangible. The source of economic value and wealth is no longer the production of material or tangible goods, but the creation and manipulation of dematerialized or intangible content. Romer (1996) explains how economic growth works by two fundamentally different types of input factors, ideas and things – intangible and tangible goods. Economic growth arises from the interaction between the intangible and the tangible process of discovery of new receipts and the transformation of things from low to high value configurations. Furthermore, Johanson (1998) claims that we are entering a new era with more organizations specializing in service and consulting, where it has become commonplace to refer to them as network or virtual or even imaginary organizations. Their strategic resources, production processes and products are much of a human character or some sort of combination of real, financial and intangible assets.

Over the years, much attention has been devoted to measure the effect of technological change. Most studies have been inspired by Solow (1957), who derives a residual or total factor productivity index under the assumption of perfect competition. Modifications of the "Solow residual" have been developed by Jorgenson, Gollop and Fraumeni (1987) and Hall

(1990). However, several difficulties have been recognized in their approach. First, an analysis of technology, technological change and productivity raises serious identification and measurement problems, as pointed out by e.g. Diamond, McFadden and Rodriguez (1978). Factor productivity analyses are typically based on the assumption of a linear or a translog production function. Parametric analyses may hence yield results that are sensitive to the assumed functional specification about the technology and the nature of technological change. Consequently, recent studies tend to reject parametric approaches to measuring technological progress, since they may suffer from the many problems associated with equation specification as well as parameter estimation. Second, the conventional approaches to measuring technological change also suffer from the fact that time has to be included as a technology variable in the underlying production function. With time representing technology, the possibility of studying cross-sectional technological changes is hampered. In addition, this approach implicitly assumes that the technological change is continuous, exogenous and smooth. Third, the assumption of perfect competition implies a one-to-one ratio between price and marginal cost, given an optimal adjustment. Furthermore, in most studies where parametric production functions are not explicitly formulated, a constant return to scale is embedded. Although total factor productivity may be measured without these two simplifications, this procedure requires an estimate of the price to marginal cost ratio and an estimate of the magnitude of the return to scale advantage, see Klette (1996).

Studies of technological change distinguish between a primal and a dual approach. Using a primal approach, technological change is typically measured in terms of changes in output that are not attributable to changes in input. Alternatively, a dual approach measures technological change in terms of the contributions to changes in costs not attributable to changes in input prices and output levels. Our paper has two major objectives. First, we present a non-parametric analysis of technological change based on a cost minimizing behavior. We have access to a unique data base containing firm-specific financial statements data for several thousands of Norwegian companies, and the proposed approach is tested on a large sample of these companies. We assume that costs may be measured by accounting data from the firms' yearly financial statements over the time period from 1990 to 1997. Second, we seek to provide evidence on the question whether differences in technological change between various industries may be explained by intangibles. The basic idea is that technological change is higher in more knowledge-based industries of the economy. Hence, our methodological approach combined with access to a unique data base of firm-specific accounting figures may provide interesting insights into the dispersion of technological change between firms as well as between industries.

Our paper is organized as follows: The dual measure of technological change is outlined in Section 2. The empirical results are presented and discussed in Section 3. Some concluding remarks are provided in Section 4.

2. A dual measure of technological change

We assume that the technology available to the firms may be represented by the general production function

$$Y_t = f_t(X_t), \qquad t = 1, 2, ..., T, \tag{1}$$

where Y_t denotes output in time period t, $X_t = (x_{t1}, x_{t2}, ..., x_{tK})$ is an (Kx1) vector of input factors in time period t, and f_t represents the technology transforming X_t into Y_t.

Technological change is usually measured by the difference in total output produced under different technologies holding the inputs constant. In general, the rate of technological change, T_c, can be measured as

$$T_c = \delta Y/\delta t \,|\, (X). \tag{2}$$

Alternatively, the rate of technological change can be measured on the cost side. A dual measure of technological change is thus

$$T_c = \delta C/\delta t \,|\, (Y, P). \tag{3}$$

P_t is input factor prices (p_{t1}, p_{t2}, ..., p_{tK}) corresponding to X_t, and the total cost of producing Y_t is given by $C_t = \Sigma_k p_{tk}x_{tk} = P_tX_t$. Consequently, a dual, as opposed to a primal, measure of technological change calculates the difference in costs with which the same output can be produced under different technologies, holding prices constant, see e.g. Stevenson (1980), Chavas and Cox (1990) and Wan (1995). See also Harberger (1998) for a broader discussion of the growth process, and his argumentation in favor of the real cost reduction concept, since this term makes one think like an entrepreneur, a CEO or a production manager.

To illustrate, we consider a production process for two periods. In period t, we are producing the output level Y_t with input factors X_t and total costs C_t. In the next period, the output level is Y_{t+1} with input factors X_{t+1} and costs C_{t+1}. We assume constant input prices, i.e. $P_t = P_{t+1} = P^T$, as well as constant output prices, i.e. $\Phi_t y_t = Y_t$ and $\Phi_t = \Phi_{t+1} = \Phi^T$, where Φ_t is the output price vector and y_t is the vector of quantity of goods sold in period t. Prices are in real terms, and the assumption of constant (real) input and output prices may be reasonable as we focus on technological change between subsequent years. Hence, we assume no input factor biases in the sense that shifts of the production isoquant down the firms' expansion path are not altering factor proportions (x_i/x_j) or factor-cost shares ($p_kx_k/\Sigma_k p_kx_k$), cf. Stevenson (1980).

With constant input and output prices, the difference (Y_{t+1}-Y_t) can be explained by technological progress and/or output expansion. Consequently, the measure of technological change is not operational unless some assumption of the structure of technology is assumed. In the literature, linear homogeneity or constant returns to scale (CRTS) characteristics of the production process are commonly imposed on nonparametric measurement of technological change. If we assume CRTS, our proposed dual measure of technological change ($TC_{t,t+1}$) is

$$\begin{aligned} TC_{t,t+1} &= (Y_{t+1}/Y_t)P^TX_t - P^TX_{t+1} \\ &= (Y_{t+1}/Y_t)C_t - C_{t+1}. \end{aligned} \tag{4}$$

The scale factor (Y_{t+1}/Y_t) gives the proportionate change in input factors X_t in the absence of technological change. When no changes in the production technology occur, $TC_{t,t+1} = 0$. Alternatively, if $TC_{t,t+1} = 0$, we have $(Y_{t+1}/Y_t) = (C_{t+1}/C_t)$, i.e. real production changes is equal to real cost changes. Hence, $TC_{t,t+1} > 0$ (<0) indicates a productivity increase (decrease), measured by the difference in total costs between period t and t+1. In this approach, there is no parametric specification or estimation about either the underlying production function or the cost function. The production function is allowed to differ between firms, as well as for one firm between different time periods. Furthermore, we do not require any assumptions about perfect competition or the use of a time trend as a technology index. We assume that firms rationally maximize the quantity of output derived from the given level of expenditure, or equivalently, minimize the costs of producing a given output. The observed input costs yield information about the firm's optimal use of input factors, and the cost measure represents a dual measure of technological change.

$TC_{t,t+1}$ represents the total contribution of technological change to cost savings. If $TC_{t,t+1}$ is normalized, i.e. divided by the total output in current period t+1, a relative measure of technological change can be calculated as

$$tc_{t,t+1} = TC_{t,t+1}/Y_{t+1}. \quad (5)$$

3. Empirical analysis

3.1 Test methodology and data

The proposed cost approach is tested on a large sample of Norwegian companies. We consider a production process with three input factors; labor (L), materials (M) and capital (K). Technological change ($TC_{t,t+1}$) is measured between subsequent years (t, t+1), and cost figures for the input factors are measured by firm-specific accounting data reported in the firms' annual financial statements. For each firm, we calculate

$$\begin{aligned} TC_{t,t+1} &= (Y_{t+1}/Y_t)\, C_t - C_{t+1} \\ &= (Y_{t+1}/Y_t)\, (L_t + M_t + r_tK_t + Depr._t) - (L_{t+1} + M_{t+1} + r_{t+1}K_{t+1} + Depr._{t+1}) \quad (6) \end{aligned}$$

where:

Y_t= total revenues in period t

C_t = total costs

L_t = wage and salary costs in period t

M_t = costs of goods sold in period t

r_t = company required cost of capital in period t

K_t = average total assets in period t

$Depr._t$ = depreciation or replacement costs in period t.

All variables, except r_t, are reported in the firms' annual financial statements. The accounting variables are deflated by using the production price index and are hence in real terms. The data are from the Dunn & Bradstreet financial statement computer data base, which contains data from the Register of annual company accounts at The Brønnøysund Register Centre - the central source of information in Norway. Submission of the annual balance of account and the auditor's report to the Centre is a requirement stated in the Norwegian Companies Act.

To obtain an estimate of the company required cost of capital, r_t, we apply the weighted average cost of capital (wacc) formula

$$r_t = r_{Et} [E_t/(E_t + D_t)] + r_{Dt} [D_t/(E_t + D_t)] \quad (7)$$

where:

r_{Et} = required cost of equity

r_{Dt} = required cost of debt

E_t = average equity in period t

D_t = average debt in period t.

The company required cost of capital (r_t) is based on the estimated cost of equity (r_{Et}) and debt (r_{Dt}), weighted by the equity- $[E_t/(E_t + D_t)]$ and debt-to-total-capital ratio $[D_t/(E_t + D_t)]$, respectively. Only a minority of the firms in the sample are listed on the Oslo Stock Exchange (OSE), and the importance of the OSE bond market as a source of financing relative to credit banks is small. Hence, firm-specific risk adjusted cost of debt and equity capital, as well as firm-specific market based debt and equities ratios, are in general not available. Instead, we use a sample estimate, and OSE listed companies may serve as a guide to estimate the sample wacc. In Gjesdal and Johnsen (1999), the historical stock market return and the treasury bond yield were estimated for various time periods. For 1990-1997, our period of analysis, the yearly stock market return and the yearly treasury bond yield were 13.2% and 7.8%, respectively. We penalize our companies with a liquidity risk premium of 1% relative to OSE companies, such that the sample cost of equity becomes 14.2%. We assume a sample credit risk premium of 1% relative to the risk-free rate of interest, which implies that the sample cost of debt becomes 8.8%. With an sample debt- and equity-to-total-capital ratio of approximately 80% and 20%, respectively, the wacc is estimated at $0.8 \cdot 8.8 + 0.2 \cdot 14.2 = 9.88\%$. The yearly inflation rate was 2.4% over the period, which yields a real weighted cost of capital for our sample of $(9.88-2.4)/1.024 = 7.3\%$. Hence, we use a real cost of capital (wacc) of 7.3% for every firm for all years over the period of analysis.

Our sample identification criteria are: i) Companies are from the industry groups 15-37 Manufacturing or 72-74 Services according to the EU industry group classification standard NACE Rev. 1, ii) Financial statements are registered for every year from 1990 to 1997, iii) The yearly company turnover is minimum NOK 1 million. By following Criterion i), we seek to provide evidence on the question whether technological change differs between various industry sectors. The basic idea is that the technological change is higher in more knowledge-based areas of the economy, i.e. higher in the service sector than in the manufacturing sector. Criterion ii) implies that we follow the same sample of companies over a time period of eight years. By implementing Criterion ii) and iii), the smallest companies, as measured by turnover, are eliminated. These companies are overrepresented in the population with respect to negative values, extreme values and missing values in the financial statements, as well as with respect to missing the complete financial statement for one or more years. The three criteria are met for a sample of 4,556 companies in the manufacturing sector and 4,103 companies in the service sector.

To reduce the influence of extreme observations, we have trimmed the sample by deleting the top and bottom 5% estimations of technological change before presenting and discussing our results. This trimming procedure reduces the number of observations to 4,102 in the manufacturing sector and to 3,693 in the service sector, i.e. a total of 7,795 companies in the sample remains. Technological change is estimated for every firm for subsequent years over the period of analysis. Since we calculate a cost of capital from average total asset values, estimates of technological change are from six subsequent periods ranging from $tc_{91,92}$ to $tc_{96,97}$. Adding the average estimate, $tc_{91,97}$, yields a total of $7{,}795 \cdot 7 = 54{,}565$ firm-specific observations.

3.2 Empirical results

Table 1 presents the results of our estimated technological change for the manufacturing and the service industry, respectively. Since our estimates of technological change are based on firm-specific yearly data, our procedure provides evidence on the distribution of technological change over years and between firms. Moreover, as pointed out by e.g. Gjesdal (1997), calculations based on national accounting data and the aggregated accounting statistics display very little variation, i.e. analyses based upon that kind of data may underestimate the volatility of individual company performance.

The table shows an average annual technological change ($tc_{91,97}$), or real cost reduction, of 0.35% in the manufacturing industry and of 0.73% in the service industry over the period 1991-1997. If we assume that the average technological change is normally distributed with mean and standard error given by Columns 2 and 3, respectively, the coefficient is significantly positive for both industries, as we see in Column 4 (p-value = 0.000). We also observe that the yearly technological change varies between –0.28% and 0.78% for the manufacturing industry and between –0.36% and 1.44% for the service industry. We further learn from the table that the average annual technological changes in the two industries are positively correlated. More important, utilising a simple test for differences, we may conclude that there has been a significant difference in technological change between the two industries over the period 1991-1997 (p-value = 0.000).

From the percentiles we see that the most efficient firms (90 percentiles) in the manufacturing industry typically realize cost reductions of at least 6-7% in a single year, while the least efficient firms (10 percentiles) realize cost increases of at least 5-6%. Focusing on the total period 1991-1997, we see that the most efficient firms have average cost reductions of at least 2% per year, while the least efficient firms have average cost increases of at least 1% per year. Annual standard errors and the belonging percentiles indicate clearly that the volatility of technological change is considerably higher in the service industry. The 10 and 90 percentiles are here typically almost twice the (absolute) value of those of the manufacturing industry. The service industry sample is characterized by a higher proportion of intangible assets than the manufacturing industry, which contribute positively to fluctuations in technological changes. More intangibles would imply a higher score on our productivity measure in the service industry, given that the source of value creation has shifted from physical content to knowledge content, i.e. to intangibles and intellectual capital. A higher productivity may thus be explained by educated and well-developed employees causing a better use of resources and more successful product changes. In Norway, the part of value creation that can be explained by intangibles and intellectual capital has become increasingly more important. Both the high level of education and the general development in the economy underscore this fact, e.g. the service industry has grown considerably over the last decade.

By utilizing firm-specific financial statements data, our approach differs from previous domestic and international studies. In addition, previous Norwegian studies cover different periods of time. Holmøy (1986) reports an annual total factor productivity growth of 0.2% over the period 1979-1984, and Holmøy, Larsen and Mæhle (1992) obtain 0.9% for the period 1971-1990. Klette (1996) reports 1.2% over the period 1972-1990. Klovland (1999) finds a long-run rate of growth in total factor productivity of about 1% per year for the period 1927-1959. These studies are all based on Statistics Norway's aggregate accounting and industry data from the manufacturing industry, constructed from reports from the about 450 largest companies (having more than 100 employees). Hence, both methodology, data samples and periods of analysis differ. Our figures fit nicely into the results from other studies of productivity in the Norwegian economy, and demonstrate that our procedure based on company financial statements is appropriate. In addition, our approach enables us to draw conclusions based on statistical inference.

Table 2 displays productivity differences over the period, measured by $tc_{91,97}$, between various industry groups within the manufacturing industry. We have not decomposed the results of the service industry accordingly, as one group contains more than 90% of the observations. We may compare the industry groups along various dimensions. The companies in Group A belong to the sheltered line of business. In addition, Group A and B may be described as labor intensive industries, while all the others may be defined as capital intensive.

We observe distinct differences between the groups. A positive technological change has taken place in all groups, except in group H. Given normally distributed averages, most estimates are statistically different from zero. To summarize, the technological change is significantly negative for firms in Group H, insignificantly positive for firms in Group A (p-value = 0.180), and significantly positive for all other groups (at the 5% level). Notice that the median value is negative for Group A, while it is positive for Group H. The results underscore that the productivity in the sheltered sector, i.e. Group A, has been low.

In Table 3, we split both the manufacturing and the service industries into three groups based upon i) size as measured by average turnover in NOK mill. over the period 1991-1997, ii) labor intensity as measured by the average ratio of labor cost to total cost over the period 1991-1997, and iii) age as measured by the year of entry. In Panel A, we give some descriptive statistics, while Panel B presents a non-parametric test as well as a regression model. Again, technological changes are measured by the $tc_{91,97}$-statistic.

First, we observe that a significant positive technological change has taken place for companies with low and medium turnover (size), both in the manufacturing and in the service industry (p-value = 0.000), while this is not true for large companies (p-value = 0.225 and 0.059, respectively). The technological change is highest for the smallest companies, which may be explained by a size effect, in the sense that small companies are more flexible and efficient organizations where the owners engage in daily operations of the firm. Second, we see a positive relationship between technological change and labor intensity. However, the tc-statistic is not significant for the most labor intensive companies in the manufacturing industry (p-value = 0.702, only 30 companies in this group). Third, we learn that age, i.e. the year of entry, plays a significant role in explaining technological changes. All categories come up with a significant score on our measure. However, the youngest companies are quite old and have been a success in the sense that they survived through their first eight years of operations, or else they would have been excluded in our sample. For all categories, we see that the technological change is higher in the service industry than in the manufacturing industry, which may be explained by the fact that companies in the service industry contain a larger proportion of intangibles, which contribute more to increased productivity than labor and capital, cf. the discussion related to Table 1.

To further increase our understanding of the importance of industry sector, age, labor intensity and size on productivity, we perform a non-parametric test of bivariate correlation between the variables and run a multivariate regression model. The two tests are on the total sample, i.e. 7,795 firms, and the results are presented in Panel B of Table 3. A dummy variable represents the industry sector (0 = Manufacturing and 1 = Service), otherwise the variables are as defined previously. We see that the Spearman's rho correlation coefficient is significantly negative between the tc-statistic and the turnover (size) variable, and significantly positive between our productivity measure and each of the other variables, labor intensity, age and industry sector. The regression results underscore the fact that technological change differs significantly between the manufacturing and the service industry, and that both the degree of labor intensity and age have a decisive positive influence on productivity (at the 5% level). However, the result for the size variable, which now has become insignificantly positive, is not replicated. Since the assumptions behind the regression model are satisfied (details omitted here), the Spearman's rho for size may be regarded as a spurious result.

4. Concluding remarks

In this paper, we have utilized a dual measure of technological change, calculated as real cost reductions, to estimate the productivity of a large sample of Norwegian companies. We have found a significantly positive technological change in the period from 1991 to 1997.

Companies in the service industry score significantly higher on our measure of technological change than those in the manufacturing industry. It also turns out that labor intensive companies have experienced positive and significant technological changes. Assuming that technological change is higher in more knowledge-based sectors of the economy, we have provided evidence that differences in technological change between various industries may be explained by intangible assets. Since labor intensive companies and service companies typically contain a large proportion of intangibles, our results indicate that this type of assets contributes more to increasing productivity than tangible assets. Finally, our results also indicate that younger companies on average are more productive than older ones.

Acknowledgements: The authors would like to thank Joachim Høegh-Krohn, Jan Tore Klovland and Kjell Henry Knivsflå for helpful comments and discussions. Financial support from the Research Council of Norway is gratefully acknowledged.

References

Chavas, J-P., Cox, T. L., 1990. A non-parametric analysis of productivity: The case of U.S. and Japanese manufacturing. The American Economic Review 80, 450-464.

Diamond, P., McFadden, D., Rodriguez, M., 1978. Measurement of the elasticity of factor substitution and bias of technical change. In: Fuss, M., McFadden, D. (Eds.), Production economics: A dual approach to theory and application. North-Holland, Amsterdam, pp. 125-148.

Gjesdal, F., 1997. Earnings: Measurement, data and estimation bias. SNF Report No. 96/1997, SNF, Bergen. (In Norwegian)

Gjesdal, F., Johnsen, T., 1999. Cost of capital, profitability and valuation. Cappelen Akademisk Forlag, Oslo. (In Norwegian)

Goldfinger, C., 1997. Intangible economy and its implications for statistics and statisticians. International Statistical Review 65, 191-220.

Hall, R. E., 1990. Invariance properties of Solow's productivity residual. In: Diamond, P. (Ed.), Growth/productivity/unemployment: Essays to celebrate Bob Solow's birthday. MIT Press, Cambridge, Massachusetts, pp. 71-112.

Harberger, A. C., 1998. A vision of the growth process. The American Economic Review 88, 1-32.

Holmøy, E., 1986. Measuring productivity, Economic Analysis. Statistics Norway, 22-33. (In Norwegian)

Holmøy, E., Larsen, B., Mæhle, N.Ø., 1992. Growth and productivity in Norway 1970-1991. Economic Survey. Statistics Norway, 16-34. (In Norwegian)

Johanson, U., 1998. The importance of intangibles and the changed nature of the firm. Unpublished manuscript.

Jorgenson, D. W., Gollop, F., Fraumeni, B.,1987. Productivity and U.S. economic growth. North-Holland, Amsterdam.

Klette, T. J., 1996. Investments in real capital, research and education as a source of industrial growth. In: Norman, V.D. (Ed.), Industrial policy and economic development. Universitets-forlaget, Oslo, pp. 85-116. (In Norwegian)

Klovland, J. T., 1999. Accounting for productivity growth in Norwegian manufacturing industries 1927-1959. Discussion Paper No 21/99, Department of Economics, Norwegian School of Economics and Business Administration, Bergen.

Romer, P. M., 1996. Why, indeed, in America? Theory, history, and the origins of modern economic growth. AEA Papers and Proceedings 86, 202-206.

Solow, R. M., 1957. Technical change and the aggregate production function. The Review of Economics and Statistics 39, 312-320.

Stevenson, R., 1980. Measuring technological bias. The American Economic Review 70, 162-173.

Wan, G. H., 1995. Technical change in Chinese state industry: A new approach. Journal of Comparative Economics 21, 308-325.

Table 1 **Technological change (tc), change in real total revenue (TR) and change in real operating profit (OP) (in per cent) in the manufacturing and in the service industry (per year and average) over the period 1991-1997.**

Manufacturing		**Mean**			**Percentiles**	
Year	**tc-stat.**	**Std.Err.**	**p-value**	**10%**	**50%**	**90%**
91-92	0.557	0.078	0.000	-5.816	0.277	7.255
92-93	0.720	0.075	0.000	-5.209	0.477	7.066
93-94	0.780	0.075	0.000	-5.282	0.440	7.382
94-95	0.013	0.070	0.853	-5.929	0.037	5.824
95-96	-0.279	0.072	0.000	-6.495	-0.141	5.695
96-97	0.323	0.073	0.000	-5.666	0.248	6.360
91-97	0.353	0.019	0.000	-1.077	0.260	1.970
Firms=4,102						
Service						
91-92	1.442	0.182	0.000	-11.053	0.655	14.614
92-93	0.884	0.166	0.000	-10.809	0.304	13.110
93-94	0.165	0.166	0.320	-11.054	0.108	11.868
94-95	0.226	0.161	0.160	-11.011	0.116	11.978
95-96	-0.358	0.160	0.025	-12.410	-0.075	11.184
96-97	1.397	0.173	0.000	-10.473	0.567	14.331
91-97	0.734	0.047	0.000	-2.295	0.458	4.245
Firms=3,693						

Table 2 Technological change (tc) (in per cent) in the manufacturing and in the service industry (average) over the period 1991-1997, classified by industry groups.

Manufacturing			**Mean**			**Percentiles**	
Firms	**Group**	**tc-stat.**	**Std.Err.**	**p-value**	**10%**	**50%**	**90%**
527	A	0.059	0.044	0.180	-1.124	-0.013	1.362
198	B	0.200	0.098	0.041	-1.550	0.092	1.947
434	C	0.432	0.045	0.000	-0.795	0.437	1.682
794	D	0.333	0.040	0.000	-1.063	0.299	1.902
293	E	0.298	0.074	0.000	-1.194	0.194	2.035
164	F	0.741	0.099	0.000	-0.690	0.560	2.776
605	G	0.562	0.049	0.000	-0.939	0.456	2.266
811	H	-0.350	0.047	0.000	-1.287	0.234	2.856
280	I	0.361	0.076	0.000	-1.213	0.199	2.259
Sum=4,106							
Service							
3,693	All	0.734	0.047	0.000	-2.295	0.458	4.245

Classification codes:

Manufacturing

A: Food products, beverages and tobacco (15-16)
B: Textiles and textile products, leather and leather products (17-19)
C: Wood and wood products (20)
D: Pulp, paper and paper products, publishing and printing etc. (21-23)
E: Chemicals and chemical products, rubber and plastic products (24-25)
F: Other non-metallic mineral products (26)
G: Basic metals and fabricated metal products, except machinery and equipment (27-28)
H: Machinery and equipment n.e.c., electrical and optical equipment, office machinery and computers, electrical machinery and apparatus n.e.c., radio, television and communication equipment and apparatus, medical, precision and optical instruments etc., and transport equipment (29-35)
I: Manufacturing n.e.c. (36-37)

Service

All: Computer service (72), Research and development (73), Other service (74)

The numbers in parentheses are the classification codes according to the EU industry group classification standard NACE Rev. 1.

Table 3 **Technological change (tc) (in per cent) in the manufacturing and in the service industry (average) over the period 1991-1997, classified by size (average turnover in mill. 1991-1997), by labor intensity (average labor cost to total cost 1991-1997), by age (year of entry) and by sector dummy (0 = manufacturing and 1 = service).**

Panel A – Descriptive statistics

Manufacturing				**Mean**			**Percentiles**	
		Firms	**tc-stat.**	**Std.Err.**	**p-value**	**10%**	**50%**	**90%**
Size	<10	2,152	0.411	0.027	0.000	-1.134	0.325	2.133
	10-200	1,784	0.305	0.026	0.000	-0.994	0.233	1.704
	>200	166	0.108	0.089	0.225	-1.436	0.020	1.736
Labor int.	<0.33	2,771	0.380	0.022	0.000	-1.037	0.282	1.986
	0.33-0.67	1,301	0.301	0.031	0.000	-1.208	0.191	1.938
	>0.67	30	0.091	0.238	0.702	-1.741	-0.052	2.305
Age	<1978	1,309	0.340	0.032	0.000	-1.056	0.216	1.913
	1978-1988	1,799	0.341	0.028	0.000	-1.127	0.250	1.946
	>1988	994	0.392	0.038	0.000	-1.049	0.315	2.031
Service								
Size	<10	2,913	0.829	0.053	0.000	-2.205	0.545	4.406
	10-200	732	0.352	0.102	0.001	-2.680	0.180	3.426
	>200	48	0.786	0.417	0.059	-2.882	0.394	4.267
Labor int.	<0.33	1,271	0.539	0.089	0.000	-3.185	0,225	4.821
	0.33-0.67	1,762	0.847	0.067	0.000	-2.174	0.583	4.325
	>0.67	660	0.808	0.086	0.000	-1.254	0.578	3.269
Age	<1978	700	0.602	0.115	0.000	-3.025	0.369	4.505
	1978-1988	1,844	0.716	0.066	0.000	-2.266	0.464	4.174
	>1988	1,149	0.844	0.081	0.000	-2.016	0.489	4.301

Panel B – Spearman's rho correlation coefficients and Regression model results

Spearman's rho correlation coefficient (Total sample = 7,795 firms):

	Size	**Labor int.**	**Age**	**Dummy**
Corr.coeff.	-0.094	0.075	0.035	0.067
p-value	0.000	0.000	0.002	0.000

Regression model (Total sample = 7,795 firms):

Variable	**Coeff.**	**Std.Err.**	**p-value**	**R-sq. (adj.)**
Constant	-7.471	3.317	0.024	0.009
Size	1.299E-07	0.000	0.073	
Labor int.	2.456E-02	0.009	0.006	**F-value**
Age	3.949E-03	0.002	0.019	19.293 (sig. 0.000)
Dummy	0.364	0.049	0.000	