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Technology and Structural Change: Productivity in the Finnish Manufacturing Industries, 1925 - 2000

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Summary

The labour productivity (LP) of the Finnish manufacturing industry has grown rapidly and consistently from 1925 to 2000 (except during the second World War). This growth has been achieved through structural change and growth in multi-factor productivity. The latest manifestation of structural change is the phenomenal success of the electronics industry in the 1990s, which has brought the level of LP in the Finnish manufacturing industry to the world's technology frontier.

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1. Introduction

Significant structural changes took place in the Finnish manufacturing industry in the 20th century and at the same time productivity grew notably. These changes transformed Finland from a backward agrarian country[1] into a modern high-tech economy at the forefront of information and communication technology (ICT) in the world. In this paper we examine this transformation process extending and updating the analysis in Heikkinen, Hjerppe & Jalava (2000).[2]

We start by describing the changes in labour productivity (LP) at the level of all manufacturing industries. What is outstanding in international comparison is the rapid catch-up in the last decade or two of the 20th century. We break down the overall productivity growth into two factors: industry-specific productivity growth on the one hand and structural changes in industry composition on the other. We will examine, whether there has taken place a shift of factors into industries with high levels of LP and/or high LP growth, and detect other differences in the developments between the industries and different time periods. We analyse the effect of structural changes on productivity by performing a shift-share analysis of labour productivity growth in 1925–2000.

Shift-share analysis (see Syrquin, 1984; Timmer & Szirmai, 2000; van Ark, 2001, and Lee & Pilat, 2001) only shows what the contribution of the shift of labour to industries with either higher levels or faster growth rates of LP as well as sub-industries' contributions to aggregate productivity growth were; it does not explain growth within industries. Therefore, we move on to analyse the multi-factor productivity (MFP) growth in different manufacturing industries. Standard neo-classical growth accounting will be utilized in the tradition of Solow (1957), and Jorgenson & Griliches (1967) who broadened the concept of substitution in Solow's classic growth accounting framework and showed that there is also substitution between different kinds of capital and labour. Output growth is decomposed into the contributions of labour, capital and multi-factor productivity. Special attention will be given to adjusting the input factors for changes in quality, for as long a period as possible. Thus the changes in labour input are hours worked adjusted for labour quality, i.e. the hours worked are cross-classified by educational level and by the average wages and salaries of each educational group. Capital input is capital services, i.e. productive capital stocks weighted with user costs. The labour and capital inputs adjusted in the above ways haven't been calculated in this disaggregated way for Finland before.

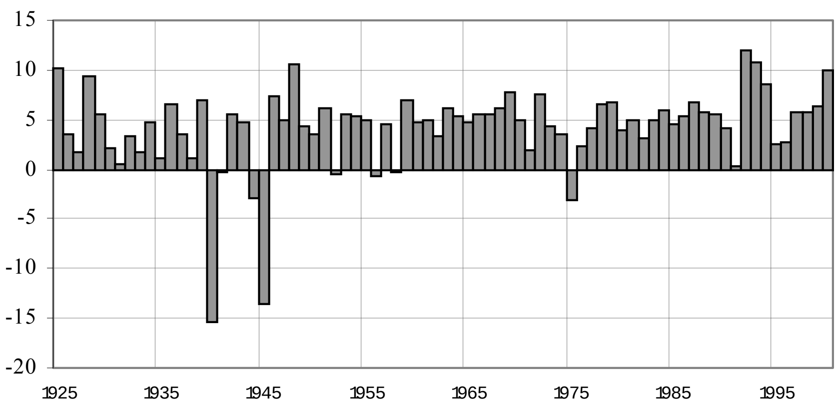
[1] The share of primary production of gross domestic product (GDP) in 1945 was still more than 40 per cent.
[2] For a wider view on the Finnish economic transformation, see Hjerppe 1989.

The paper is organized followingly. In Section 2 the LP growth in the manufacturing sector is examined and in Section 3 the effect of structural change on LP is analyzed. Section 4 contains the results of the growth accounting calculations and Section 5 concludes.

2. Productivity growth and catch-up

Labour productivity in Finnish manufacturing industries grew from 1925 to 2000 at the average rate of 4.1%.[3] Growth accelerated from the pre-war to the post-war period and reached record level in the 1990s (see Figure 1). The average annual growth rate of LP was 3.9% in 1925−1938, 0.5% in 1938–1948, 4.2% in 1948–1960, 5.1% in 1960−1974, 4.4% in 1974–1990, and 6.2% in 1990–2000. Growth was, thus, more rapid after 1960 than before that. It was also more even. The variation of coefficient of growth rates, which was 102% for the whole period, was 77% in 1925−1938, 75% in 1948–1960, 30% in 1960−1974, 52% in 1974–1990, and 60% in 1990–2000.

Figure 1. Annual changes of labour productivity in manufacturing industries, 1925-2000.



Calculations based on: Hjerppe et al. (1976); Statistics Finland's National Accounts Database

Labour productivity grew exceptionally fast in the 1990s. This was due to a structural shift from extensive to intensive growth, with a significant step-up in multi-factor productivity, following Finland's severe economic recession in the early 1990s. Extensive growth means growth achieved through investment in capital goods, whereas intensive growth here means that growth is achieved through MFP increases. Micro-level studies (e.g. Maliranta, 2001) have found evidence of "creative destruction" in the 1990s, i.e. that firms

[3] From 1925 to 1959 labour quantity is persons employed and from 1960 onwards hours worked.

with weaker productivity performance exited the market when the economy slumped, and that the then released capital and labour shifted to more profitable firms, resulting in a step-up in aggregate productivity. Maliranta also found that the number of firms that strongly focused on R&D-investments and exports increased, which also strengthened the structural change.[4]

The 1990s was a decade of Finnish productivity catch-up. The labour productivity of the Finnish manufacturing industry grew rapidly in comparison with other developed countries (Table 1). Finnish manufacturing industries caught up with and even surpassed the level of US value added per hour by 1996, which is quite remarkable since in 1960 the Finnish level was less than half of the US equivalent and behind other West European economies, which also were clearly behind the US. Three other countries also had in 1998 a level of labour productivity higher than the US, i.e. Belgium, the Netherlands and Sweden; Belgium had the highest level of labour productivity of all countries surveyed by van Ark & Timmer (2001) and OECD (2001). (It can be seen in Table 1 that Finland somewhat caught up with the Netherlands 1960–1998. Belgium also starting from a low level in the 1960s had also caught up with the Netherlands and surpassed Finland.) However, because of the strong economic growth in the late 1990s, the US left all but Finland behind in 2000. The most remarkable performance is Japan's. Her relative level of value added per hour increased four-fold 1960–1996, to over eighty per cent of US level, but by 2000 the level of labour productivity had back-stepped to somewhat more than seventy per cent of the US level.

Table 1. ICOP Estimates of levels of labour productivity in manufacturing, 1960–2000 (value added per hour, USA=100)

	1960	1973	1987	1996	1998	2000*
Netherlands	50.2	87.0	105.4	108.9	103.7	95.3
Belgium	42.2	67.0	99.8	104.0	107.5	96.0
Finland	45.5	56.1	74.3	103.5	102.4	106.6
USA	100.0	100.0	100.0	100.0	100.0	100.0
Sweden	55.3	88.3	87.4	99.4	100.8	95.1
Japan	19.9	47.5	67.5	83.2	73.5	70.4
UK	45.9	52.5	58.0	61.1	57.8	55.2

* preliminary estimate.

Sources: van Ark & Timmer (2001) and OECD (2001).

[4] Scarpetta (2001) summarises the effects of firm-level dynamics into four main points: i) a large part of aggregate labour productivity growth is the sum of what happens within individual firms, ii) labour productivity growth also benefits from the exit of low productivity units and the entry of firms experiencing rapid technological changes (e.g. in ICT-producing industries), iii) new firms provide a relatively larger contribution to multi-factor productivity – possibly because they have a more efficient blend of capital and labour than old firms, and iv) larger firms tend to have a better survival chance than small ones.

The rapid productivity growth in manufacturing also helped bring the overall level of Finnish GDP per hour worked closer to that of the US. The level of Finnish LP was in 1960 only 42 per cent of the US level, and as much as 87 per cent in 2001 (in 1996 EKS US dollars) according to the results as reported by the Groningen Growth and Development Center (http://www.eco.rug.nl/ggdc/) web site in September 2002. The fact that the whole economy has not performed as impressively as the manufacturing sector, reflects the larger public sector in Finland and that LP in other industries than those either producing or using ICT has been less than satisfactory. Indeed, Jalava (2002) shows that when the level of LP of the Finnish non-residential market sector is normalized to 100, the level of LP in ICT-producing industries[5] in 2001 is 195, in ICT-using industries[6] 137 and in other industries only 79.

3. Labour productivity and structural change

3.1 Labour productivity

The Finnish manufacturing industry employed 150,000 people in 1925. In 1974 the number of workers had almost quadrupled to 570,000. The early 1980s started a decreasing trend in industrial employment, which was 460,000 in 2000. The major structural changes were the shrinking of textiles, clothing and leather products as well as saw-milling and other timber industries. In the textile, clothing and leather industries even the production volumes have decreased since the middle of the 1980s, after the collapse of exports to the Soviet Union. The paper and pulp industries have kept their shares almost stable. The fastest growing branch was the metal industry, where the electric and electronic appliances are shown separately from 1960. The electric and electronic appliances industry has been by far the fastest growing branch since the Second World War. It was the most important growth sector of the whole economy in the 1990s (see Tables 2 and 3).

[5] The ICT-producing industries are in Jalava (2002) defined as encompassing industries: Manufacture of electrical and optical equipment (ISIC 30, 31, 32, 33), Telecommunications services (ISIC 642) and Computer software and services (ISIC 72).

[6] The ICT-using industries are in Jalava (2002) defined as encompassing industries: Manufacture of pulp, paper and paper products (ISIC21), Publishing and printing (ISIC 22), Manufacture of chemicals and chemical products (ISIC 24), Wholesale trade and commission trade (ISIC 51), Post and courier activities (ISIC 641), Financial intermediation and insurance (ISIC 65, 66, 67), Renting of machinery and equipment (ISIC 71), Research and development (ISIC 73) and Other business activities (ISIC 74).

Table 2. Number of employed in manufacturing industries, 1925–2000

	1925	1938	1960	1974	1990	2000*
Textile. clothing and leather product industries	23,700	45,300	82,500	81,400	34,100	16,800
Saw-milling and other timber industries	47,800	48,900	59,000	66,000	38,800	31,800
Paper and pulp industries	16,200	22,900	39,500	56,600	46,200	39,000
Metal industries[a]	22,500	43,600	97,300	153,100	148,400	145,400
Electric and electronic appliance industries	..	..	19,400	37,200	42,100	69,000
Other industries	38,500	60,700	112,700	171,000	194,300	157,100
Manufacturing industry total	148,700	221,400	410,400	565,300	503,900	459,100

[a] Includes electric and electronic appliance industries in 1925 and in 1938.
* Preliminary figure.
Sources: Hjerppe, Reino et al. (1976); Statistics Finland's National Accounts Database.

Table 3. Distribution of industrial value added by major branches, 1925–2000 (%)

	1925	1938	1960	1974	1990	2000*
Textile, clothing and leather product industries	12.4	14.6	12.3	8.6	3.4	1.5
Saw-milling and other timber industries	23.6	10.3	11.6	9.8	6.3	4.4
Paper and pulp industries	17.7	18.4	14.3	16.0	13.0	18.0
Metal industries[a]	14.0	21.9	25.4	26.8	28.4	24.1
Electric and electronic appliance industries	..	..	4.1	5.9	9.6	25.1
Other industries	32.3	34.8	32.4	32.9	39.3	26.9
Manufacturing industry total	100.0	100.0	100.0	100.0	100.0	100.0

[a] Includes electric and electronic appliance industries in 1925 and in 1938.
* Preliminary figure.
Sources: Hjerppe, Reino et al. (1976); Statistics Finland's National Accounts Database.

Over the whole period the differences of the labour productivity development in various industries are small varying from 3.0% in textiles, clothing and leather products, 3.2% in metal industries, 3.7% in saw-milling and other timber industries to 4.4% in paper and pulp (Table 4). Paper and pulp industries have, in general, been successful, being able to transform from a simple pulp and low quality paper producer to a top performer in the world markets, providing high-quality papers. The other good performer has been the electric and electronic industry, where particularly the development in the 1990s has been outstanding.

Table 4. Compound average annual growth rate of labour productivity by industry, 1925–2000 (%)

	Textile	Timber	Paper	Metal[a]	Electric	Manufacturing industries total
1925–2000*	3.0	3.7	4.4	3.2	..	4.1
1925–1938	2.0	2.7	6.5	2.2	..	3.9
1938–1948	–0.2	0.5	–2.5	0.1	..	0.5
1948–1960	2.3	4.0	4.2	4.5	..	4.2
1960–1974	4.9	4.3	5.1	4.9	5.7	5.1
1974–1990	4.2	4.3	4.8	4.6	5.2	4.4
1990–2000*	3.4	4.8	6.0	3.4	14.2	6.2

[a] Includes electric and electronic appliance industries in 1925–1960. * preliminary estimate.
Calculations based on: Hjerppe, Reino et al. (1976); Statistics Finland's National Accounts Database.

During the 1930s depression almost all industries experienced severe shocks in demand and, accordingly, production. Labour productivity also suffered and slowed down, it even decreased in metal industries. Paper and pulp industries were in the middle of a swift boom of investments, which led to considerable productivity gains even during the deepest depression, and the production volumes of paper and pulp also rose. Saw-milling improved its productivity while production volumes stagnated during the early 1930s. After the depression LP started to improve in all industries again, and in paper industry the development was exceptionally favourable.

The Second World War closed the export markets of paper and pulp and halved the labour productivity from the pre-war levels; the productivity levels were not regained until the middle of the 1950s. In saw-milling and other timber industries the war directed demand from sawn timber to fire-wood; productivity development slowed down but did not decline. Textiles, clothing and leather industries as well as metals suffered from various shortages of inputs and moderate declines in labour productivity. A large decline in LP occurred in the metal industries in 1945–1946 when the war industry needed to be transformed into a war reparations industry and possibilities of renewing machinery and equipment were limited because of a shortage of foreign currency.

After the war labour productivity continued to rise with a very fast pace in most branches of the manufacturing industry. A gradual easing of import restrictions improved the machinery and equipment in industry as well as opened up export markets. Some beginnings of these developments were seen in the late 1950s, but the easing of trade restrictions on a larger scale only started with the Finnefta agreement in 1961.

The slowest LP development was seen in textile, clothing and leather product industries, a sheltered home-market industry at that time. The development was again fastest in paper and pulp industries as well as metal and electric industries. Also saw-milling and other timber industries had very favourable developments.

3.2 Structural change

To ascertain the impact of structural change on labour productivity in Finland we use the so called shift-share method (for more details see Syrquin, 1984, and for recent applications Timmer & Szirmai, 2000; van Ark, 2001, and Lee & Pilat, 2001). Using the shift-share methodology we can decompose LP growth into the effects of productivity growth within the industry and effects due to structural change. The level of labour productivity at time t is:

$$LP_t = Y_t / H_t = \sum_{i=1}^{n} \frac{Y_{i,t} H_{i,t}}{H_{i,t} H_t} = \sum_{i=1}^{n} LP_{i,t} S_{i,t} , \qquad (1)$$

where Y is output, H is labour quantity, i is industry (n=1,…,n) and S_i is the share of industry i in total manufacturing employment. The change in LP levels can be expressed as:

$$LP_t - LP_{t-1} = \sum_{i=1}^{n} \left(LP_{i,t} - LP_{i,t-1}\right) S_{i,t-1} + \sum_{i=1}^{n} \left(S_{i,t} - S_{i,t-1}\right) LP_{i,t-1} + \sum_{i=1}^{n} \left(S_{i,t} - S_{i,t-1}\right)\left(LP_{i,t} - LP_{i,t-1}\right), \quad (2)$$

where the first term on the right-hand side is within-industry productivity growth, i.e. the contribution of sub-industries to aggregate productivity growth, the second term is the static shift effect, i.e. the net change in labour share weighted with previous years productivity level (an increase in labour shares of industries with a high LP level will cause a positive static effect) and the third term is the dynamic shift effect, i.e. the change in labour shares weighted with the change in LP (an increase in labour shares of industries with an above average LP growth will cause a positive dynamic effect). When each term in equation 2 is divided by LP_{t-1} the equation is in a growth rate form.

The results of the shift-share analysis are shown in Table 5.[7] On the whole, and quite expectedly so, the within-effect was the most important factor in determining labour productivity growth. Changes within industries are of course important though not visible with shift-share analysis. The growth picture has, however, varied interestingly. Both the

[7] The period 1938–1948 with a negligible LP growth rate due to the unusual war years has been left out.

periods 1925–1938 and 1960–1974 are similar with respect to the contribution of the shift-effects being negative.

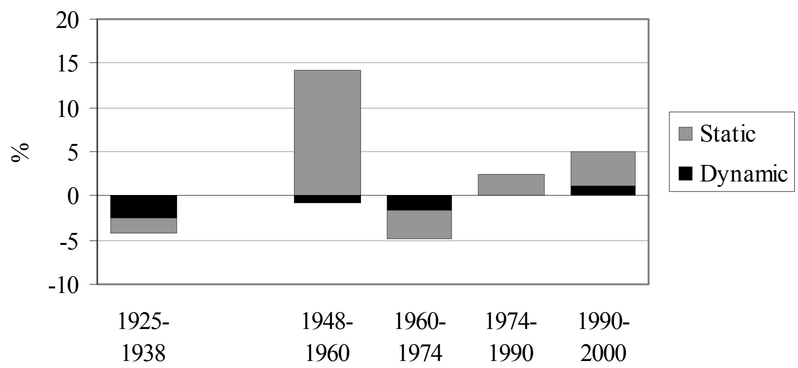
Table 5. The impact of structural change on labour productivity growth in manufacturing, %.

	1925–2000	1925–38	1948–60	1960–74	1974–90	1990–2000*
Within	98.3	104.1	86.5	105.0	97.7	94.9
Static	2.2	–1.6	14.3	–3.2	2.2	3.8
Dynamic	–0.5	–2.5	–0.8	–1.7	0.2	1.2
Total	100.0	100.0	100.0	100.0	100.0	100.0

* preliminary estimate.
Calculations based on Hjerppe et al. (1976) and Statistics Finland's National Accounts Database. May not sum to totals due to rounding.

After the war large structural changes were taking place, with a clear shift of labour to industries with above average level of labour productivity contributing 14.3% of labour productivity growth 1948–1960; even if the compound growth rate of LP was below the long term average rate during that period. It isn't, however, unusual for structural change or technological advance to boost productivity with a significant lag. In the years 1974–1990 structural change started to have a positive impact again, with somewhat more than 2% coming from the shift-effects (see Figure 2).

Figure 2. The impact of static and dynamic shift-effects on labour productivity, %.



Sources: see Table 5.

In the 1990s the pace of structural change once again picked up. The within-effect contributed 95% of the labour productivity growth, and the shifts all together 5%. The manufacture of electric and electronic equipment – which is a major producer of ICT – by itself accounted for 35.0 percentage points of the 94.9 per cent within-effect in the 1990s, as well as for 11.9 percentage points of the 3.8 per cent static shift-effect and 1.8 percentage points of the 1.2 per cent dynamic shift-effect. In other words, the shift-effects of the other manufacturing industries were clearly negative in the 1990s. These figures show the dominant position of the electric and electronic industries in the productivity developments and are consistent with van Ark's (2001) findings that the combined contribution of ICT-producing and ICT-using industries to Finland's labour productivity growth of the whole economy was 74 per cent in the late 1990s.

The shift-share analysis has of course its limitations, which Lee & Pilat (2001) list followingly. Firstly, labour productivity is only a partial productivity measure. Secondly, the assumption is that the marginal productivity of the labour moving into or out of the industry equals average productivity, and thirdly, if output growth is positively dependent on productivity growth, the effect of structural change may be underestimated.

4. The engine of growth: multi-factor productivity

The shift-share analysis above has shown that general advance in productivity, rather than structural changes, explains most of productivity growth within Finnish manufacturing industries in 1925–2000. In the following we break down the productivity growth into three elements: capital deepening, improvement in labour quality and multi-factor productivity (MFP).

We start by looking at the aggregate production function:

$$Y_t = A_t F(K_t, L_t) \qquad (3)$$

where, at any given time *t*, aggregate value added *Y* is produced from aggregate inputs consisting of capital services *K* and labour services *L*. The level of technology or multi-factor productivity is here represented in the Hicks neutral[8] or output augmenting form by parameter *A*. Assuming that constant returns to scale prevail in production and that product and factor markets are competitive, neo-classical growth accounting gives the share-weighted growth of outputs as the sum of share-weighted inputs and growth in multi-factor productivity[9] (see, e.g., Jorgenson et al. 1987):

[8] "… a technological innovation is neutral (Hicks neutral) if the ratio of marginal products remains unchanged for a given capital/labor ratio." (Barro & Sala-i-Martin 1995, p.33).

[9] Embodied technical change is captured by the capital input term, whereas disembodied technical change is captured by MFP.

$$\hat{Y} = v_K \hat{K} + v_L \hat{L} + \hat{A}\,, \tag{4}$$

where the ^-symbol indicates the rate of change and where the time index t has been suppressed. The weights v_K and v_L sum to one and represent the nominal income shares of capital and labour respectively. Both labour and capital have been corrected for quality changes for as long a period as possible (see Appendix for the technical details).

Equation 4 can be rearranged as:

$$\hat{Y} - \hat{H} = v_L(\hat{K} - \hat{H}) + v_L(\hat{L} - \hat{H}) + \hat{A}\,, \tag{5}$$

where the term on the left side is the change in labour productivity, the first term on the right side is capital deepening, i.e. an increase in capital services per hour worked, and the second term is the improvement in labour quality which is defined as the difference between the growth rates of labour services and hours worked. The third term is a general advance in multi-factor productivity. In Finnish manufacturing industries MFP has traditionally been the most important source of LP growth as can be seen in Table 6. This differs from the US growth picture, where capital deepening has been the most significant contributor to LP growth in domestic private output 1959–1998 as shown by Jorgenson & Stiroh (2000). It is also somewhat surprising, knowing the high inputs in education in the post-war period, that the calculation shows a very low impact for the factor. The low contributions of capital deepening and labour quality may also reflect the difficulty of measuring the impacts.

Table 6. Contributions to labour productivity in the manufacturing industry, 1948–2000.

	1948–2000*	1948–1960	1960–1974	1974–1990	1990–2000*
Growth rate of labour productivity[a]	4.9	4.2	5.1	4.4	6.2
Contributions from[b]					
Capital deepening	0.9	0.8	1.4	1.5	–0.2
Labour quality (education)	..	..	..	0.2[c]	0.3
Multi-factor productivity	3.8	3.4	3.6	2.7	6.0

* preliminary estimate, [a] per cent, [b] percentage points, [c] from 1976.
Calculations based on Hjerppe et al. (1976) and Statistics Finland's National Accounts Database. May not sum to totals due to rounding.

Because of data limitations the MFP calculations are performed only for the years 1948–2000. The results of the MFP calculations in Table 7 show some rather uneven developments for the post-war period. First there was favourable, accelerating growth in all industries followed by a stand-still or retardation in paper and electric industries and a slow-down in the others during the oil crises years of the second half of the 1970s. These were again followed by new acceleration induced particularly by the development in electric and electronic industries as well as in paper industry.

Table 7. Compound average annual growth rate of MFP by industry, 1948–2000 (%)

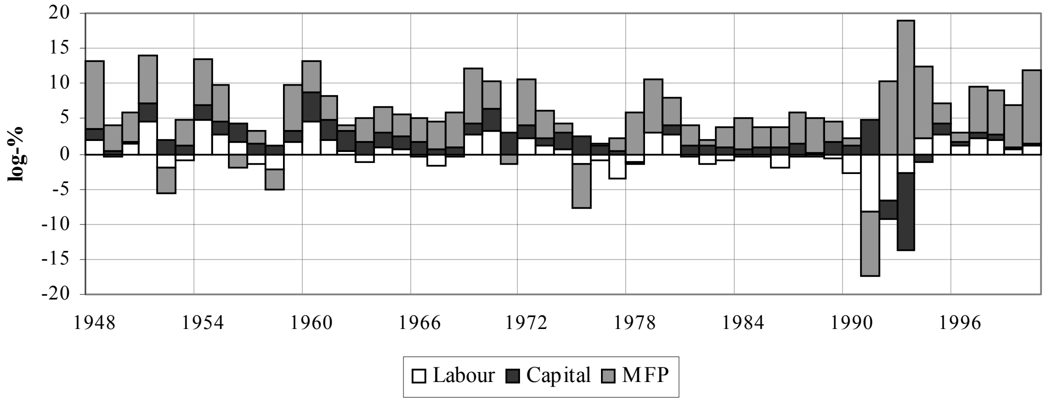
	Textile	Timber	Paper	Metal	Electric	Manufacturing industries total
1948–2000*	2.4	3.4	3.6	3.9	..	3.8
1948–1960	2.0	3.3	2.3	5.0	..	3.4
1960–1974	3.3	2.9	3.9	4.1	3.9	3.6
1974–1990	2.5	2.6	2.6	3.4	3.9	2.7
1990–2000*	1.5	3.9	5.5	3.6	10.7	6.0

* preliminary estimate. Calculations based on: Hjerppe, Reino et al. (1976); Statistics Finland's National Accounts Data Base.

We also show the contributions of labour, capital and multi-factor productivity for the whole manufacturing industry decomposed in Figure 3 The interesting feature is the high share of MFP in total output. Since MFP catches all unmeasured factors such as disembodied technical change, organisational improvements, economies of scale and measurement errors, Abramowitz (1956) quite rightly called the residual a *'measure of our ignorance'*. In most years MFP exceeds the contributions of labour and capital by a large margin. In his monograph on "inefficient capital" Pohjola (1996) discusses the many facets of the economic growth in post-war Finland. Pohjola's main point is that even though Finland had a world record in investments in the period 1960–1990 the sacrifices made (i.e. the foregone consumption) did not yield as much benefit as such a high investment ratio should have.[10] In the neo-classical sense, where MFP is seen as exogenous, our results corroborate Pohjola's views on inefficient capital. The growth contribution of capital input has on the whole been rather modest (see Figure 3).

[10] Pohjola uses data from the Penn World Table, Mark 5.6.

Figure 3. The contributions of labour, capital and MFP to manufacturing output growth, 1948-2000, log-%



Calculations based on: Hjerppe, Reino et al. (1976), Statistics Finland's National Accounts Database.

Recently Jalava & Pohjola (2002) have shown that the bleak picture of capital's small contribution to output growth has been somewhat offset by ICT capital. Jalava and Pohjola calculate that the contribution of ICT capital to non-residential market sector output growth has increased from 0.2 percentage points in 1975–1990 to 0.7 percentage points in the latter part of the 1990s. At the same time non-ICT capital's contribution has shrunk from 0.8 percentage points to –0.4 percentage points. This is in line with our observations about the dominant role of ICT in the recent developments.

In principle, information and communications technology can enhance economic growth in three different ways. Firstly, the production of ICT goods and services contributes directly to the total value added generated in an economy. Secondly, the use of ICT capital as an input in the production of other goods and services can make a contribution to economic growth. The benefits from ICT use are even likely to outweigh the benefits from ICT production, which are limited to just one sector of the economy. Thirdly, ICT can have spill-over effects on multi-factor productivity.

In Jalava's and Pohjola's results, the contribution from the use of ICT to output growth has risen considerably in Finland during the late 1990s. In addition to this there has been a large increment in multi-factor productivity growth in the market sector. An OECD study (OECD 2001b) finds that about 20 per cent of the MFP growth in the total economy can be attributed to the ICT industries in Finland. However, the output contribution of ICT to growth has increased even faster than the contribution from ICT use, which raises the question whether the productivity gains experienced in the ICT producing industries will diffuse to other sectors.

5. Conclusion

In this paper we have studied productivity in the Finnish manufacturing industries from 1925 to 2000. We started by breaking the overall productivity growth into two factors: industry-specific productivity growth and structural changes within manufacturing sector. We assessed the significance of these two factors by performing a shift-share analysis of labour productivity growth in 1925–2000. In addition to this, we analysed multi-factor productivity growth using standard neo-classical growth accounting (adjusting the input factors for changes in quality). For labour and capital inputs quality adjustments have not been accounted at such a disaggregated level in Finland before.

The structure of the manufacturing industry has changed since the 1920s, with textiles, clothing, leather product industries as well as saw-milling and other timber industries loosing ground and metal and particularly the electric and electronic appliance industries gaining. Paper and pulp industries have pretty much kept their share. The labour productivity differences between the separate industries have, however, been rather small in average; the exceptions having been paper industry, where the overall productivity growth has been faster and electric and electronic industries, which has reached unexceptional rates in the 1990s.

The shift-share analysis we performed showed that the impact of productivity growth within industries was clearly the largest. The static shift effects, or movement to industries with higher (or lower) productivity levels, and dynamic shift effects, or movements to industries with faster (slower) rates of productivity growth, were of much lesser significance and sometimes even had a negative impact. It has to be noted, however, that the division of manufacturing into just a few large industries leaves a lot of the movement of labour undetected. On the other hand, the relatively small productivity growth differences between industries may obscure the impacts of the structural changes in this kind of a calculation.

The multi-factor productivity (MFP) calculations show that in Finnish manufacturing industries MFP has been the most important source of labour productivity growth. This is in contrast to for example the USA, where capital deepening has mattered most. This result is in line with Matti Pohjola's results about the high investment ratio of the post-war period not bringing the appropriate growth.

The overall results show very fast productivity development in the Finnish manufacturing industry, which has contributed to a closing of the gap between productivity levels in Finland and Western Europe. Indeed, the Finnish manufacturing industry's productivity story until the 1990s is one of catching-up, and in the 90s mostly due to ICT-production (and to a smaller extent ICT-use), a story of technical change. The MFP calculations quantify the effect of the disembodied technical change, but still leave an important question to be answered by future research: why has the MFP growth been so strong in the Finnish manufacturing industries?

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Appendix

This appendix explains how capital and labour inputs are defined and measured in the analysis carried out in the paper. For a more comprehensive coverage of the various concepts, see for example OECD (2001c). Following Jorgenson & Stiroh (2000), we use a geometric age-efficiency pattern to construct productive capital stocks. The productive capital stock is defined as:

$$K_t = K_{t-1}(1-d) + I_t = \sum_{\tau=0}^{\infty}(1-d)^{\tau} I_{t-\tau} \ ,$$

where I is gross fixed capital formation, d is the rate of depreciation and t denotes time. The user cost of capital is defined as the rate of return plus depreciation minus capital gain/-loss:

$$r_{ijt} = p_{ij(t-1)}q_{it} + p_{ijt}d_{ijt} - (p_{ijt} - p_{ij(t-1)}),$$

Here, for industry i and asset type j, r is the rental price, p designates the price index for new capital goods and q is the rate of return. The rate of return can be estimated residually as

$$q_t = \frac{capital\ income - \{p_t d_t - (p_t - p_{t-1})\}K_{t-1}}{p_{t-1}K_{t-1}},$$

where K is real capital stock and pK the nominal capital stock, i.e., the market value of the capital stock. The user costs are used to aggregate the productive capital stocks by asset type (and/or by industry). We assume that aggregate capital services are a translog function of the services of individual assets (see Jorgenson, Gollop, Fraumeni (1987)). Thus the aggregate volume index of capital services is:

$$c_{jt} = \frac{K_{jt}}{K_{j(t-1)}} = \prod_i \left(\frac{K_{ijt}}{K_{ij(t-1)}}\right)^{v_{ijt}},$$

where the weights ν are defined as

$$v_{ijt} = \left(\frac{r_{ijt}K_{ijt}}{\sum_i r_{ijt}K_{ijt}} + \frac{r_{ij(t-1)}K_{ij(t-1)}}{\sum_i r_{ij(t-1)}K_{ij(t-1)}}\right)/2\,.$$

Here c is the volume index of capital services[11] and K denotes the productive capital stock.

The asset types and average service life years that we use for capital goods are shown in Table A1. They are identical to the ones used by Statistics Finland. Capital goods are also classified by industry which explains the variations in service lives shown in Table A1. Household consumption goods, inventories and land are not included in our definition of capital goods.

Table A1: Capital goods' asset types and average service lives

Asset	Average service life, years
Non-residential buildings	35–45
Civil engineering and other structures	25–40
Transport equipment	7–12
Other machinery and equipment[12]	11–28
Computer software[13]	5

As a measure of labour input we used hours worked adjusted for labour quality. The hours worked are cross-classified by educational level and by the average salary of each educational group. In aggregating the volume index of labour input[14] it is assumed that the aggregate input is a translog function of the quantities of individual labour types:

$$\ln L_t - \ln L_{t-1} = \sum_l \overline{v_l}\left[\ln L_{lt} - \ln L_{l(t-1)}\right],$$

where the weights are given by the average shares of each labour type in the total value of labour compensation:

$$\overline{v_l} = \frac{1}{2}\left[v_{lt} + v_{l(t-1)}\right]$$

and

$$v_{lt} = \frac{p_{lt} L_{lt}}{\sum_l p_{lt} L_{lt}},$$

with p_l being denoting the wage rate of labour type l. A six-category classification of labour by the level of education is applied. To obtain data on hourly wages by educational groups, we use the longitudinal census file for the years 1975, 1980, 1985, 1990 and 1995 (the intermediate years were interpolated). It contains information on 6.4 million people and their

[11] We were able to construct capital services series from 1961–2000, for the period 1948–1960 the productive capital stocks as such were used.
[12] The service lives are decreased by 0.7–1.0 per cent per year in 1960–1990 and 0.4–0.5 per cent per year after 1990.
[13] From 1975 to 2000.
[14] We were able to construct a quality adjusted volume index for labour input for the years 1976–2000. For the years 1961–1975 the hours worked as such were used, and for 1925–1960 persons employed were used.

economic activities. For the years 1996–99, we use the labour force survey and the wage structure statistics[15]. The wage structure statistics is not yet available for 2000, so we assumed the same structure as in the year 1999. All data were adjusted to national accounts levels.

[15] The wage structure statistics was only available at the level of the manufacturing industry, so for the sub-industries we assumed the same structure of wages and education as in the aggregate industry.