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

Keskusteluaiheita
Discussion papers

George F. Ray

THE DIFFUSION OF TECHNOLOGY IN FINLAND

No 258 14.04.1988

ISSN 0781-6847

RAY, George F., THE DIFFUSION OF TECHNOLOGY IN FINLAND. Helsinki : ETLA, Elinkeinoelämän Tutkimuslaitos, The Research Institute of the Finnish Economy, 1988. 53 p. (Keskusteluaiheita, Discussion Papers, ISSN 0781-6847 ; 258).

ABSTRACT: In view of the rapid postwar economic advance of Finland, the purpose of this paper is to analyse the adoption and diffusion of 'new' industrial processes and to assess the technological level of the Finnish industry. This is done on the micro level, by studying the introduction and spread of a dozen major postwar process innovations in the steel, materials, consumer goods, 'high tech' and energy industries. International comparison is the main method used to assess Finnish willingness to innovate (how soon adoption followed the innovator), the speed and the present level of diffusion. Various measures are used to tentatively quantify these aspects and to fit the Finnish data into the international background. The message of the study is that Finnish industry was not particularly quick to adopt new technologies developed elsewhere - although in some areas such innovations had been almost immediately introduced - but once the new technology was adopted its spread was very rapid. The most recent (1985-6) level of diffusion of the selected technologies is high; in some of the 'high tech' cases there appears to be some lag but these branches have recently been advancing fairly rapidly; and there are a few sectors where Finnish enterprises have become world leaders.

KEY WORDS: diffusion of innovations, technology transfer, technological level, international diffusion, Finnish industry, Finland.

THE DIFFUSION OF TECHNOLOGY IN FINLAND

GEORGE F. RAY

Contents:

April 1988

Preamble: the Finnish scene

During the last seventy years Finland has developed into a progressive, industrialised country, with the result that by the middle of the 1980s the level of its economic development as measured by GDP per head at current exchange rates was comparable to that of Germany, ahead of most European countries (table 1). And although Finnish national output per head is still the lowest amongst the Nordic countries, the historically huge differences have disappeared: they are now relatively small - 14 per cent against oil-producing Norway and only 9 per cent as compared with Sweden, the undisputed leader in the Nordic camp.

The Finnish economic achievement becomes even more significant if set against the country's more remote past: around 1910, 80 per cent of the economically-active population was employed in the primary sector - in agrarian Denmark this proportion was only 36 per cent, whilst in the same year Sweden already employed one third of its labour force in industry. The latter share was not attained by Finland until 1970, sixty years later. Estimates of national income levels for the early part of the 19th century are uncertain, but according to some estimates Finland was at that time one of the poorest areas of Europe.(1) What we do know on the basis of more reliable later data is that - quoting Vartia and Vuori(2) - "in GDP per capita terms Finland had been above the average European level already before the war and the prewar output level of 1938 was again reached in 1946".

Recent calculations of the OECD also show how much nearer Finnish productivity is now to that of her Nordic neighbours (or indeed to the leading USA) than it was only 25 years ago. These estimates (table 2) concern labour productivity in the business sector of the OECD countries based on purchasing-power parities. (No correspondence can be expected between the data in tables 1 and 2 because of varying exchange rates and the effect of including purchasing-power parities in the estimates underlying table 2.)

Thus, the economic development of Finland, although starting late and from a low level, has certainly been impressively rapid. The bulk of it occurred after the 1939-45 War, a period filled with traumatic experiences for the Finnish people. Finland eventually emerged from the war burdened with substantial reparation commitments which obliged her to deliver a wide range of specifically detailed products. These commitments exceeded by a considerable amount the then available industrial potential of the country and forced its marked extension; this required great effort and sacrifice, leading Landes to remark in his classical study of economic and technological progress that the American press, "never failed to laud little, honest Finland for punctually meeting her engagements".[4]

Having overtaken the combined level of other Nordic countries (Denmark, Norway and Sweden) in the late 1960s, the share of manufacturing in Finnish GDP reached its peak in 1974, when it was 26 per cent, as against 22 per cent in Scandinavia; in the early 1980s this Finnish indicator remained similarly higher than that of the other Nordic countries and was almost exactly identical to the average of all other OECD countries.[5]

Table 1. GDP per person

	1986 levels and exchange rates	
	US $ (000s)	Finland=100
Switzerland	20.4	142
USA	17.2	119
Norway	16.4	114
Denmark	16.1	112
Sweden	15.7	109
Iceland	14.9	103
Germany	14.7	102
Finland	14.4	100
Canada	14.0	97
Luxembourg	13.3	92
France	12.8	89
Austria	12.5	87
Netherlands	11.9	83
Belgium	11.4	79
Italy[a]	10.5	73
UK	9.6	67
Ireland	6.9	48
Spain	5.9	41
Greece	4.0	28
Portugal	2.8	19

Source: OECD, as given on p.4 of 'The Nordic alternative', *The Economist*, 21 November 1987.

(a) Including black economy.

Table 2. Labour productivity levels[a]

Finland = 100

	1960	1970	1980	1985
Finland	100	100	100	100
Denmark	140	118	106	106
Norway	154	132	133	134
Sweden	155	138	134	129
Austria	96	100	106	104
Belgium	132	126	130	127
France	120	124	128	130
Germany	128	126	123	123
Greece	46	63	72	62
Ireland	..	81	88	83
Italy	109	136	131	122
Netherlands	168	159	154	153
Spain	102	101	115	117
Switzerland	197	170	134	129
UK	152	121	105	107
Canada	215	173	151	147
USA	307	234	175	163
Japan	77	95	101	104

Source: OECD. (See *Economic Outlook*, no. 43, December 1987, table 23, page 45.)

(a) Figures concern the business sector and are based on purchasing-power parities for 1985. Productivity is calculated as real output divided by total employment.

Table 3. Finnish energy consumption[a]

Million tonnes coal equivalent

	Commercial energy[a]	of which: primary electricity[b]	Non-commercial energy[c]	Total
1949	3.9	1.8	5.6	9.5
1973	23.3	1.8	7.0[d]	30.3[d]
1985	25.6	4.3	8.4[d]	34.0[d]

Source: UN, 'World energy supplies', various issues.

(a) Coal, petroleum, natural gas and primary energy.
(b) Hydro and nuclear electricity. The official (UN) conversion to coal equivalent occurs "on the basis of prevailing efficiencies of central electric stations"; in 1949, 1000KWh was taken as equivalent to 0.6 tonnes of coal, in 1973 and 1985 as 0.123 tonnes.
(c) Fuelwood, peat, other wood and industrial waste materials.
(d) Estimate. (To be revised.)

Perhaps nothing demonstrates better the changes on the Finnish scene than the growth of the country's consumption of commercial energy: its level in the last decades was so much higher than in the interwar years (and those immediately after the war) that it illustrates a difference in kind - and not only in degree - due to the changed structure of the economy and to the marked rise in Finnish standards of living (table 3).

Introduction

Almost four hundred years ago, Francis Bacon, one of the architects of the scientific revolution, wrote in his 'Novum Organum', "The benefits inventors confer extend to the whole human race". Inventors are scattered all over the world; their inventions, when they materialise, become innovations, and it is by means of diffusion that 'the human race' benefits.

'The human race' is a vague concept: it is fragmented into nations; so too is the world fragmented, geographically, into countries like Finland. Assuming that these inventions/innovations are 'Good Things' and relatively freely available, the degree of benefits conferred depends on the willingness of the relevant people in any country - civil servants, industrialists and other businessmen - to adopt the novelties, and on the speed at which they are disseminated across the board, throughout the whole economy.

Any major innovation, whether an industrial process or product, or any new method in the non-industrial sphere, is bound to be superior to the earlier technology in some sense; it can reduce the labour or other input into the production process, improve the quantity or quality of output, or provide a new product or service - otherwise it would not have succeeded. It follows that the adoption and wider diffusion of such an innovation helps to increase the efficiency of the economy.

The scope of this study

Many factors have contributed to the rapid economic development in Finland. Innovative spirit was one of them; this, however, poses problems. The first question is: how to define it? The second question is how to quantify it.

The various methods of estimating, usually at macro level, the contribution to economic growth by quantifiable factors - labour and capital - are well known. The fact that the residual between actual growth and the amount which could be imputed to these factors as the joint contribution of technological progress, improved management methods, better work organisation, 'learning by doing' and all other unquantifiable factors is also obvious.

This 'residual' approach cannot account for more than a limited explanatory value - some call the residual the 'coefficient of ignorance',(6) because it reflects the impact of a mixture of influencing factors which defy disentangling. Nevertheless, this approach deserves mention here for two reasons. First, it gives a quantified idea of the effect on the rapid growth of the Finnish economy of factors other than labour and capital input; and secondly, recent research work in this area at ETLA provides all the relevant data. For convenience, these data are reproduced in table 4 in summary form.

Table 4. Contribution to the growth of manufacturing production in Finland

	Annual average per cent changes	
	1960-73	1973-86
Output growth	6.3	3.0
Contribution of:		
labour	0.7	-0.8
capital	2.2	1.0
all other (residual[a])	3.4	2.8
Residual as % of total	54	93

Source: Ref. (5), table 3.

(a) Called 'total factor productivity' in the source.

Table 5. The 'residual' contribution in per cent of output growth

Industry:	Food	Textiles & clothing	Wood	Paper & pulp	Chemical	Basic metals	Metal products
Period:							
1960-73	42	95	82	57	37	42	55
1973-86	91	320	(a)	148	67	86	72

Source: as for table 3.

(a) Negative growth = -0.1%; 'residual' +1.7% a year.

According to these calculations, in the period spanning 1960-73 about one half of the growth in Finnish manufacturing, and in 1973-86 almost all, was due to factors other than capital and/or labour. The contribution of this 'residual' varied greatly by industry but it was substantial in each branch, in some cases - where employment actually fell - exceeding the extent of growth (table 5); and it was consistently higher in the second, recent period than in the first.

Technological progress and the adoption and diffusion of innovation must have accounted for a considerable part of this 'residual' contribution but it is difficult to separate reliably the impact of innovative activity from all other factors summarily included in the 'residual'.

Therefore another, more direct approach had to be applied, starting not from the macro level but from the micro one: the innovations themselves.

A number of important postwar innovations have been selected for closer study. (The selection was slightly influenced by the availability of data for international comparison.) Two most noteworthy facts were required for each of these innovations: the date at which it was first adopted in Finland, and a measure of the speed and degree of diffusion throughout Finnish industry. Information of this kind is not generally available from the usual statistical sources; it had to be specially collected for this purpose.

Comparing Finnish and international data in various ways - the date of introduction of some new technology in Finland compared to the date of the original innovation, the speed of diffusion and its degree related to the situation in other countries - should give a fairly good idea of the attitudes and achievements of Finnish industry in the area of innovations, and the introduction and dissemination of new technologies.

Two major points should be remembered, however. First, if it were possible to collect the required basic information - Finnish and international - for all major and minor new technologies and innovations in all industries in a certain period (say, the postwar decades) and, moreover, in some way to quantify their impact on growth as well as somehow construct a scheme for international comparison, then a complete assessment could result, indicating the contribution of innovative activity to growth as well as Finland's place in the international league. The practical difficulties of such a maximalist approach are, however, obviously insurmountable.

Secondly, it must be borne in mind that international comparison in the sense described is not like an Olympic race. The economic or social environment of each country - and often each company - is different; indeed, it can be so different that an innovation, a new technology or any other novelty which appears most beneficial in one country or one company may be rejected, or its adoption delayed, on very rational grounds, in another. Bearing this caveat in mind, it is nevertheless believed that the analysis of a number of cases may illustrate the Finnish position in a useful manner.

The method in detail

Finland's innovative efforts can only be assessed by means of international comparison. For this purpose two types of data have been used: Finnish data, collected from industrial statistics and special local inquiries by ETLA; and international data which, though originating from many sources, basically stem from a number of publications,[7 to 11] which together cover almost the full circle of the diffusion of certain major innovations from invention to saturation.

These studies, as reflected by their titles, analyse selected major postwar process innovation - that is, new technologies, in various phases: when they were new; later in their mature stage; and finally when approaching saturation. Work on them has been continuing, though with major interruptions, for twenty years (1967 to 1988).

The original objectives of the first of three rounds of the aforementioned studies were to assess the scope and extent of the diffusion of selected, then new, industrial technologies in a number of countries (Finland not being among them); to establish the international differences in the level and speed of their diffusion; and to make an attempt to account for the differences between countries. Ten new processes, introduced in the twenty years after the end of the war, were selected for the inquiry, which was conducted on parallel lines in several countries. Each technology was described in detail, including its characteristics and advantages, in separate chapters. The reports[7,8] pinpointed considerable differences in the date of introduction and also in the following diffusion of the new processes. This led to the cautious suggestion that diffusion might have tended to be slower in the pioneering countries (which had to deal with teething troubles) and faster in the more enterprising followers.

Many factors were found to influence the adoption and diffusion of new techniques, such as overall profitability (stemming from labour-saving, energy conservation or improved usage of materials, increased yield, higher quality, etc.); relative wages and other factor prices; market characteristics, institutional differences; the nature of the industry; and management attitudes. Some could be econometrically verified, others not.

The second round of research continued to survey the same technologies in their mature phase. The emphasis was less on international comparison (although that was not neglected) than on the further development of the technologies (i.e. incremental innovations), the survival of the earlier technology and any specific factors hindering or promoting the spread of the once new, and by then mature, technology.[9, 10]

The third round[11] completed the circle: it followed the same technologies to the last phase, when they attained a high degree of penetration, eventually approaching saturation.

For some of these technologies saturation is the end of the story - but only of <u>this</u> particular story: the progress of technology does not end there. As the once new technique becomes conventional and traditional, saturating the market, sooner or later something newer may, and very likely will, emerge to replace it.

The aim of this study is to assess Finland's place as compared with the international background as illustrated by these and some other technologies.

A brief description of the 'new' technologies follows; there would seem to be no need to go into greater detail, mainly because the technologies selected are fairly well known, but also in view of the detailed accounts in the published sources quoted. Short chapters discuss the adoption and diffusion of each technology in Finland, in some cases extending to additional relevant aspects; this leads to some tentative conclusions.

The technologies studied

Each of the technologies covered in this study was new some time after the war. The research work that led to their application might have gone back in some cases to earlier years, but they are all considered postwar novelties: that is, the first commercial use of the innovation by the pioneering company anywhere in the world occurred after 1945. Other companies in the same country and elsewhere could have taken over the new technology later on; for them it was new, an innovation, though otherwise it would be considered a case of transfer of technology or the diffusion of innovation.

The technologies (or innovations, or new processes) studied fall into five groups:

A) The steel industry

1. Basic oxygen steelmaking (BOP)

This technique, introduced in 1952 in Austria, revolutionised integrated steelmaking and has now almost wholly replaced the earlier dominant open hearth (Siemens-Martin) system.

2. Continuous casting (CC)

A CC machine replaces three stages of the conventional technology for processing liquid steel into semi-finished products: the casting of ingots, the soaking pit and the blooming mill. This innovation also originated in Austria, but in the early years it was restricted to special steels; its application to bulk steel production started in the mid- 1960s.

B) Materials

3. Special presses in papermaking (SP)

More efficient water removal from the 'web' (the dispersion of fibres in water) was the purpose of these various types of presses, allowing the paper machine to be run faster, thereby raising its production capacity.

4. Tunnel kilns in brickmaking (TK)

Traditionally, bricks were burnt in Hoffmann-type kilns, consisting of a series of chambers. The fire was started in one chamber and when the bricks there had been burnt, it was moved to an adjacent chamber, continuing along the circuit. The bricks were stationary - the fire was moving. The arrangement of the tunnel kiln is exactly the opposite: the fire is stationary and the bricks move through the firing zone.

5. Float glass (FG)

This technique, introduced in Britain in 1959, was an entirely new concept in flat glass production. First it was used for making plate (thicker) glass. By entirely bypassing the annealing, grinding and polishing steps - delicate operations with a very high risk of breakage - it represented a vastly superior technique but it was some time before it could be further developed to make sheet (thinner) glass as well.

C) Consumer goods

6. Shuttleless looms in cotton-type weaving (SL)

Since their introduction in the 1950s, all the main types of shuttleless looms were developed further and gradually started to replace the old automatic shuttle loom. SLs are labour saving, produce fabrics of high and uniform quality, and reduce noise in the weaving shed, that unavoidable nuisance of the shuttle loom. Gradual development has reduced the original disadvantages of the new looms and increased their flexibility.

7. Gibberellic acid in malting/brewing (GA)

The conversion of grain into malt is significantly accelerated by the application of gibberellic acid at the beginning of germination, the result being savings in time, increased yields and better quality.

D) High technology

8. New plate-cutting methods in shipbuilding (PC)

The new methods were, in this order, optical lofting, photo-electrically-controlled cutting and numerical control by tape programming. These were introduced from 1950 onwards and greatly eased the cutting of heavy steel plate, the 'tailoring' to design of the main shipbuilding material. The novelties turned into 'high technology' when the whole cutting operation became computerised.

9. Numerically-controlled machine tools (NCMT)

The study was restricted to NCMTs in metalworking. The input of numerical data into the machine, and the control of its action by the instruction transmitted, was computerised early in the 1970s; this helped to extend greatly the viability and efficiency of NCMTs.

10. Industrial robots (IR)

11. Flexible/automatic manufacturing systems (FMS)

These are relatively recent applications of microelectronic control. Each of these two techniques is at a relatively early stage of diffusion.

E) Energy

12. Nuclear electricity (NE)

Even the opponents of nuclear power generation admit that NE is one of the great innovations of this century. The minor troubles and major disasters (particularly Chernobyl) as well as the unsolved problems surrounding the eventual dismantling of nuclear power stations throw now, with the benefit of hindsight, a light on nuclear electricity which is markedly different from the general views in earlier years when nuclear power was 'en vogue'.

* * *

Whilst in the case studies that follow we attach considerable importance to the original innovation, let it be underlined at the outset that without significant incremental innovations probably none of the technologies studied would have achieved the widespread diffusion it actually did. In the course of its wider adoption (and also simply as a consequence of 'learning by doing') the new process has usually been further improved and developed by means of minor, often gradual, changes and additional innovations. These were aimed at widening the area of adaptability of the new technology, extending the scope of its operation and/or raising its efficiency.

Incremental innovations enabled the oxygen process to cope with ores of almost any composition and to make a wide range of steel qualities; major development of continuous casting was a condition of its adoption by large, integrated steelworks for bulk steel casting. The worldwide acceptance attained by the float process would have been unthinkable without its extension from thick plate to the making of thinner window glass. Many additional changes were required before shuttleless looms could handle almost the whole array of textile fabrics, including those of many colours or special structure. The rapid development of the control mechanism and significant changes in machine tool design have made numerically-controlled machine tools almost universally acceptable.

Incremental innovations, in the above sense, were important in all the cases studied here. In the case of one of the processes studied, the development was indeed so important that the original innovation lost its validity: the then new plate-marking and cutting methods in shipbuilding were replaced by computer; the idea remained but the instrument changed, reflecting the rapid progress in technology and the science underlying it.

Similarly, it was rapid progress that led to a change of opinion over a period of time with regard to the importance of two of the processes covered: special presses in papermaking and gibberellic acid in malting. Over twenty years ago (when the work on the studies quoted first started, serving the bases for international comparison[7,8]) industrialists and technologists considered them to be major innovations in their industries; now, with the passage of time, their view (at least in Finland) is different, interpreting these changes in the productive process as almost routine developments, innovations of secondary importance.

The steel technologies

1952 was a decisive year in the history of steelmaking: two new techniques, BOP and CC, were introduced in that year in the state-owned steelworks of Austria. The basic oxygen process (BOP), after significant further technical development, became the dominant method of integrated steel manufacture in the following two decades. BOP gradually replaced the generally applied open hearth (Siemens-Martin) method, rather as the latter was substituted earlier this century for the Bessemer converters.

BOP made a slow start: it was not until 1957 that a larger number of steelworks in various countries introduced it and wider diffusion occurred from 1960 onwards, when world production of oxygen steel crudely doubled every two years, exceeding the 100 million tonnes mark in 1966. By then BOP accounted for about two thirds of all crude steel output in three countries: Japan, the Netherlands and Austria, the pioneer. All other countries were lagging behind.

In Finland, BOP was introduced in 1968. Finnish steel output in 1969 was almost one million tonnes; 30 per cent of that output came from electric furnaces, the new BOP converters produced 54 per cent and the remaining 16 per cent was accounted for by traditional open hearth plants. In the same year, the conventional methods still accounted for a higher share of national output in North America and in most European countries. By adopting BOP on a fairly large scale in 1968, the Finnish steel industry raised its technological level in a sudden jump. It compared favourably with other Nordic producers (table 6) and the new plants provided a good base for the industry's subsequent major expansion.

The Finnish steel industry grew rapidly in the 1970s: its output rose from one million tonnes in 1969 to around 2½ million tonnes at the turn of the decade and 2.63 million tonnes in 1984. This is particularly noteworthy when set against the depressing wider background: from 1973 to 1982 total crude steel output in the Western world fell by one fifth. All the expansion in Finland originated from the new BOP technology (table 7).

1968 was also the year of the introduction in Finnish works of the other major steel innovation, <u>continuous casting</u> (CC). By then the initial troubles associated with this technology had been sorted out and its adoption for the manufacture of bulk steel - as distinct from special steel - had also been resolved. Nevertheless, CC was still in its infancy; although known since its first introduction (for special steels) in Austria, the quantity of continuously cast steel was small; only in Sweden, where CC started in 1963, did its share approach 10 per cent of crude steel output.

Table 6. The Nordic steel industry in 1969 and 1979[a]

	Denmark	Finland	Norway	Sweden
Crude steel output, million tonnes				
1969	0.48	0.98	0.85	5.32
1979	0.80	2.46	0.92	4.73
Share in Nordic production[b]				
1969	6	13	11	70
1979	9	28	10	53
Share by technology[b]				
1969 open hearth	96	16	-	25[c]
electric	4	30	54	41
BOP	-	54	46	33
1979 open hearth	39	-	-	6
electric	61	14	47	41
BOP	-	86	53	53

Source: *Annual Bulletin of Steel Statistics for Europe*, UN, New York.

(a) 1969 was the first year of fully operational BOP plants in Finland, and 1979 the first year without any output from the traditional (open hearth) method.

(b) Per cent.

(c) Including the Thomas system.

Table 7. Crude steel output in Finland, 1969-1984

Million tonnes

	1969	1972	1975	1978	1981	1984
Total output	1.0	1.5	1.6	2.3	2.4	2.6
of which:						
open hearth	0.2	0.1	0.1	(a)	-	-
electric	0.3	0.3	0.3	0.3	0.3	0.4
BOP	0.5	1.1	1.2	2.0	2.1	2.2

Source: As for table 6.

(a) Less than 0.05.

In Finland, CC machines complemented the new BOP installations. The two major new technologies progressed almost hand in hand; CC's share in output moved nearly parallel with that of BOP.

By 1975, three quarters of Finnish crude steel was continuously cast, the highest diffusion in the Nordic countries and probably in the world (the CC share in that year was 31 per cent in Japan, around 25 per cent in Germany, Italy and Spain, 21 per cent in pioneer Austria, and less everywhere else). Ten years later, in the mid-1980s, CC reached practically near saturation in Finland (table 8). Only in Japan, Austria and Denmark was the 1985 diffusion rate similarly high.

Special presses in papermaking (SP)

Before turning to this technology in detail, three points should be discussed briefly in order to characterise the Finnish paper industry.

First, forests are Finland's most important resource; their importance in the country's life has been paramount from all angles. The forest industries were in the past the leading exporters and have remained one of the chief pillars of Finnish export earnings ever since.

One of the natural endeavours has been to process the primary product of the forests - wood - into gradually more refined forms: sawnwood, woodpulp and paper (concentrating here on the main product stages). This road has been followed with remarkable success: in 1985, Finland was the fourth largest producer of newsprint in the world (with an output of 1.8 million tonnes) behind Canada, the US and Japan; and the sixth largest producer in the world of other paper and board (5.6 million tonnes) - in both cases slightly ahead of Sweden.[12] Paper and board now account for two thirds of all forest product exports - a result of gradual development over more than a hundred years (table 9).

Secondly, the capital stock in the Finnish paper industry is relatively very young, possibly the youngest in the world. The average size of Finnish mills is very large - much larger than Swedish or American plants (table 10); this is not a new situation - the proportions have changed little in the past twenty years.

Thirdly, Finnish companies engaged in the production of papermaking machinery have for some time been one of the world leaders. One economic historian wrote that by the mid-1960s, "12 per cent of the world's papermaking machinery was being bought from Finland".[13]

These three points have an important bearing on the case study of the innovation of special presses on paper machines. The (non-Finnish) industrial experts approached over twenty years ago considered this innovation as being of importance; this was the reason it was selected for study, starting with the detailed description of the innovation in the main report.[3] According to the same source, the innovators were Swedish and US firms in this case.

By now the technology of special presses is regarded by industry experts as having been of relatively minor importance in an historical perspective. There are nowadays a number of solutions to the problem that special presses were supposed to tackle; some of these new approaches take a quite different form, making it rather difficult to identify SPs in their original form any more. It is similarly difficult to quantify the diffusion of the SP technology in the usual form.

Table 8. CC in OECD countries

Percentages in crude steel output

	1975	1980	1985
(i) Nordic countries[a]			
Denmark	43	73	100
Finland	76	90	94
Sweden	22	49	81

(ii) Other countries in 1985[a]

80 per cent and over		50 to 80 per cent		20 to 50 per cent	
Austria	93	Belgium	60	Canada	44
France	81	Italy	79	Luxembourg	28
Germany	81	Spain	58	Netherlands	39
Japan	91	UK	55	Portugal	43[b]
				USA	42

Source: As for table 6.

(a) No CC has been reported for Norway and Switzerland. (b) 1984.

Table 9. Finnish exports of forest products

	1866	1886-90[a]	1896-1900[a]	1913	1970	1980	1986
Value of exports of all forest products, million FMK	16	40	94	227	5.4[b]	22.9[b]	30.7[b]
Per cent share of processed products[c]	2	7½	17	30	73 (48)[d]	69 (52)[d]	80 (68)[d]

Source: (2) and ETLA.

(a) Annual averages. (b) Thousand million FMK. (c) Pulp, paper and board.
(d) Paper and board only.

Table 10. Average size of paper plants

	Thousand tonnes/year		Finland = 100	
	1970	1986	1970	1986
Finland	150	214	100	100
Sweden	89	145	59	68
USA	73	124	49	58

Source: Ehrnrooth-Kirjasniemi, 'Prospects of forest industries, especially from the point of view of branch rationalization', *The Finnish Economic Journal*, 3: 1987.

Considering, however, the three points listed above, it can be said with a fair amount of certainty that

- SPs were taken into use in Finland at the same time as elsewhere and probably just some months or a year behind the Swedish paper industry;
- all paper machines in Finland use these types of presses (or those techniques that replaced SPs).

Two pieces of evidence support the industry's above statements: first, in an industry where the productive equipment is young (or the youngest), the technological level must be high and the best available, incorporated in the relatively new plant and machinery; this also means that the diffusion of any innovation is also high in that industry.

Secondly, the leading makers of paper machines obviously incorporate worthwhile innovations into their products (whether invented by them or by others); thus, the young and growing Finnish paper industry simply could not avoid obtaining 'the newest'.

Tunnel kilns in brickmaking (TK)

The history of the adoption of the tunnel kiln for burning clay building bricks (as distinct from other ceramic products) is somewhat obscure. As early as 1840, a patent for a tunnel type kiln was granted in Denmark, but it remained a mere patent on paper; then in 1858 came the German innovation of the Hoffmann kiln which dominated the brick industry for the next hundred years. Nevertheless, a few tunnel kilns for bricks were built during that period, such as in 1902 and again in 1926 in Britain, as well as in a similarly isolated manner in Germany too. The experiences gained there were probably the basis of the first brickworks using tunnel kilns, built in 1942-3 in Finland.

This date of adoption was early; elsewhere the first postwar tunnel kilns were built between 1951 and 1955, for instance in Sweden, Austria, Italy, Germany and the UK.

By 1980, some 85 per cent of Finnish clay brick output was produced by TKs and this share had risen to 95 per cent by 1986. This compares well with the diffusion elsewhere (table 11). In fact it means saturation: all but two out of 18 brickworks use TKs (the two exceptions being brickworks that operate only temporarily).

Float glass (FG)

The first float line for the production of plate glass came on stream in 1959 at the plant of the inventor/innovator, Pilkington Brothers (then still a private firm) in the UK. Plate glass is the thicker variety of clear flat glass which then accounted for about one third of the flat glass making capacity of the Western world. The remaining two thirds of production was directed towards sheet glass, chiefly window glass, with a thickness of 3 mm. For this, the float process was not originally appropriate; later on, however, further developments extended the range of the float, enabling it to replace the earlier sheet processes as well. As a result, by the mid 1980s the old system of plate glass making had practically disappeared in the industrial countries and the majority of the sheet capacity had also been replaced by float lines (table 12). Thus, the diffusion of FG has been relatively rapid in the advanced countries; the developing and centrally-planning countries lag behind somewhat.

Table 11. The diffusion of tunnel kilns

	Per cent of clay bricks produced in TKs	
	1980	1986[a]
Finland	85	95
France	90	92
Germany	90	95
Italy	90	92
Sweden	95	95
UK[b]	72[b]	74[b]

Source: (10), (11) and ETLA.

(a) Partly estimated.

(b) Not strictly comparable: because of the high fuel (carbon) content of certain clays, the TK is not universally acceptable.

Table 12. The worldwide diffusion of the float process

	Numbers		
	1971	1982	1986
Manufacturers holding a licence	15	30	35
Countries of the licensees	10	22	29
Float glass plants[a]	29	88	105

Source: (10) and Pilkington.

(a) In operation, under construction or projected.

One of the factors limiting the further spread of the float technique is its relatively large output: even a small float line produces more than the total requirements of a small market. This particular aspect is very relevant to the curious history of the float technology in Scandinavia and Finland. Because it reveals some interesting points, the background from the 1984 report is reiterated here (no. 10, pages 56-8).

> "The earlier study (no. 8, page 212) reported on what was then the newest flat glass plant in Europe, erected on a greenfield site in Korsør, Denmark, as a joint Danish-Swedish venture. The plant was built and operated on the Pittsburgh principle (the traditional method of drawn glass) for two reasons; first, that the demand in the whole of Scandinavia would lag behind the capacity of one single float line; and secondly, that the float process could not then produce thinner sheet glass, for which there was a demand. The first argument was valid, but decisive only if the product range of the float process remained restricted to plate glass. The second argument was an example of technological shortsightedness since soon after the then new plant came on stream, the float process was developed further and started to produce thinner sheet glass; thus this argument rapidly became invalid. This brought about marked changes in the Scandinavian glass industry.
>
> In 1976, Pilkington's new float plant started production in Sweden. In 1977 the Norwegian flat glass producer (Drammen) went bankrupt; in 1978 the other Swedish flat glass producer (Emmaboda) stopped producing flat glass; and finally in 1982 the Danish plant at Korsør, built just over a decade earlier, was closed down. In all three cases the chief, though not exclusive, reason was competition from the new float plant, which could produce more cheaply. There seems to be no doubt, however, that for any one of the Scandinavian countries a float plant would be 'too big'.
>
> There is now only one flat glass producer beside the Pilkington factory left in the Nordic countries, that in Finland... In spite of Pilkington's interest in the firm it has not been converted to the float process, presumably in view of the small market in Finland."

However, technological development can be quick and business policy can also change rapidly: Pilkington raised its interest in the Finnish company, the only maker of flat glass in Finland, to 50 per cent, and in 1987 the float technique replaced the earlier Pittsburgh method in Finland.

The capacity of the new plant was small, 55 thousand tonnes a year (the worldwide average capacity of float plants is around 125 thousand tonnes).

It appears that smaller float plants have become viable (presumably as the result of further development); indeed, the capacity of the new plant is smaller than Finnish domestic requirements, currently estimated at 80-85 thousand tonnes. The plan apparently is to supply the excess requirement from the Swedish float plant; moreover, an exchange between the Finnish and the Swedish (Pilkington-controlled) plants, permitting a degree of specialisation for each of them, is also a possibility, creating another example of Nordic co-operation (albeit under the Pilkington umbrella).

Shuttleless looms in cotton-type weaving (SL)

The traditional machine in the weaving shed used to be the shuttle loom, first hand operated and later automated. Attempts at carrying the thread across the loom by a method other than shuttle go back a long way and simple rapier-type solutions have been available since the 1920s. But it is only since 1950 (the year when Sulzer's projectile-type loom came onto the market) that a variety of more sophisticated versions have appeared.

The first known users of SLs were French weavers in 1953 (although it is possible that Swiss firms, nearer to Sulzer, might have preceded them). Between 1953 and 1958 SLs were adopted in Germany and the USA and also in Britain, Sweden and Austria, but in the latter three countries on a very minor (probably just trial) scale. Finland followed on a similar basis in 1959 when eight Sulzer looms were taken into use.*

Diffusion of SLs started slowly in Finland; more than twenty years later, in 1980, the entire stock of new type looms was still only about

*Information obtained from the Association of Finnish Textile Industries.

300, some 15 per cent of all looms. The adoption rate of the Finnish cotton-type textile industry (by far the biggest in the Nordic area) was in 1980 almost identical with that of the whole of Western Europe (14 per cent).

During the first half of the 1980s there has been a large change, however. Contraction of the textile industry has resulted in the reduction of the loom park by two thirds, but this was combined with the installation of further SLs, so that in 1985 all looms were of the new type. The diffusion rate for SLs in Finland of 100 per cent compares with 35 per cent in Western Europe. The only country with a similar 100 per cent diffusion rate is Sweden, whose much smaller industry followed a path almost identical to that of Finland.

Although the number of looms is now much smaller, the productivity of the new-type looms is much higher than that of the earlier shuttle looms (table 13).

Table 13. Cotton-type weaving in Finland, 1980-85

	1980	1985
1. Number of looms, thousand		
all looms	2.1	0.7
of which: shuttleless	0.3	0.7
per cent share of SLs	15	100
2. Nordic comparison:		
All looms		
Denmark	0.7	0.7
Norway	0.7	0.5
Sweden	0.5	0.2
Per cent share of SLs		
Denmark	-	25
Norway	32	48
Sweden	35	100
3. Finnish textile production (indices)		
(A) Textiles (ISIC321)[a]	100	80.4
(B) Spinning, weaving and finishing (3211)[a]	100	77.9
(C) Cotton weaving (321123)[b]	100	56.8
4. Loom productivity		
(A) Number of looms, index	100	33.3
(B) Production per loom (3C:4A)	100	171

Source: 'International textile machinery shipment statistics, International Textile Manufacturers' Federation, Zurich; ETLA.

(a) According to official industrial statistics.

(b) Current value added deflated by the producer price index for textiles.

Gibberellic acid in malting/brewing (GA)

Maltsters and brewers first used GA in Sweden and Britain; in both countries the first use was in 1959. At the time it was considered an important novelty, but later on the innovation's significance declined.

In the mid 1960s just over half of both the British and Swedish production of malt was treated with GA, and this share rose to over 70 per cent in the UK by 1970.

In a few other countries, Germany for example, food laws prohibit the use of GA; there is no such legal prohibition in Finland. Indeed, Finnish malting companies have been using GA since the 1960s, but they use it only for specific beers and not all the time. They now consider it a standard procedure and not an indicator that in any way determines the technological level of their industry. (It is for this reason that quantification of the diffusion of GA was not available.)

New plate-cutting methods in shipbuilding (PC)

The first new method to replace the traditional marking and cutting by hand of steel plates for ships was optical lofting, a Swedish innovation dating from 1950. Later that same year the photoelectrically-controlled cutting machine was introduced in the UK. Numerical control followed in 1961, also in the UK (in those days by transferring the drawing to the cutting machines by programmed tape).

This was a case of innovations aimed at the very same process following each other in quick succession. In Finland, the year of introduction was 1955 - somewhat later than in the pioneer countries and Germany, but well before France and Italy (table 14). By 1966, all the big

Table 14. New plate marking and cutting methods[a] in shipbuilding

	Year of introduction[b]	Diffusion rate in 1966[c]
Finland	1955	95
France	1960	68
Germany	1953	66
Italy	1962	48
Sweden	1950	80
UK	1950	36

Source: (7) and ETLA.

(a) The methods listed in the text. Finnish data concern the whole industry, figures for other countries relate to firms participating in the 1968 inquiry, as reported in (7).

(b) Of any of the listed methods.

(c) Per cent share of steel cut by new methods in total steel used.

Table 15. NCMT: selected indicators

	Finland	Sweden	France	Germany	Italy	UK	USA	Japan
Year of first use	1962	1958	1957	1962	1960	1956	1955	..
Approximate share in total machine tool output, per cent and (year)	30 (1986)	35 (1981)	..	20 (1980)	22 (1981)	18 (1981)	35 (1980)	50 (1980)
Number of NCMTs produced, thousands (rounded), 1985	0.06 (1986)	..	2	14	3	3	5	45
Number of NCMTs installed								
thousands	1.7	4	31	64	11	26	103	28
per cent in total MT stock and (year)	2[a] (1985)	3 (1980)	4 (1985)	6 (1985)	2 (1981)	3 (1982)	5 (1983)	3 (1980)

Source: (6), (10), (11); ETLA. Partly estimated.

(a) The Finnish stock increased to 2200 in 1986 and nearer to 3000 in 1987, raising the per cent share to about 3 %.

Finnish shipyards were using one of these techniques and the diffusion rate was high.

With the arrival of the computer, all these 'new' techniques became obsolete; they were gradually abandoned. By 1986 they were almost wholly replaced by computer-controlled systems in Finland (as they were in other major shipbuilding countries). The only remaining users of non-computerised methods are very small yards engaged in repair work and using only marginal quantities of steel.

Numerically-controlled machine tools (NCMT)

Developed in the USA, in the beginning NCMTs were primarily suited to performing certain operations on certain batch sizes. Drilling, milling, turning and polishing were the areas initially covered by NC machines; smaller batches and one-off pieces (unless very complex) were made on traditional machine tools, larger runs on automatic machines, and NCMTs were applied to medium-sized batches. Considerable development work followed to extend the scope of NCMTs in all directions; the final stimulus, however, came in the 1970s from the combination of NCMTs with computers. NC became CNC - computerised numerical control.

Nowadays, CNCMTs can be applied economically in most metalworking spheres, almost regardless of the complexity of design, the number of programs required or the repetition of the same operation (although automatics are still preferred for very long runs).

NCMTs were first introduced in 1955 in the USA; the UK followed in 1956, other countries somewhat later. The first installation in Finland in 1962 coincided with the first in Germany.

The Finnish engineering industry started to make NCMTs much later, in 1977. In that year Germany produced about 2,000 NCMTs and the Japanese (with 5,400 produced) were already the world leader. From that time onwards output in Finland has risen: in 1985 about 10 per cent of all machine tools were NCs (by number of units) and in 1986 this share had increased further to some 13 per cent. By value the NC share is much higher: 25 per cent and approximately 30 per cent correspond to the two yearly figures given for units.

These percentage shares, however, mean little because of the small size of the machine tool industry in Finland. The total production of NCMTs in 1986 was 60 units, which accounted for 13 per cent of the total machine tool output of about 500 units. These figures can hardly be compared with those of major producers cited in table 15. The comparison based on units and values produced should also be interpreted with some caution because one NC unit can vary from a simple punching machine to a sophisticated machining centre.

From the point of view of the spread of NC machines in the metalworking industry - and, in a sense, the technical level of the industry - the whole NC stock and its relationship to the total (NC plus non-NC) machine tools is more illustrative than the question of whether the NCMTs are home-produced or imported. Stock figures, however, are not easy to collect and therefore the international data in table 15 concern different years. By 1985 there were 1,700 NCMTs installed in Finland; in 1986 their number had risen to 2,200 and by 1987 this figure was nearer 3,000. Thus, in 1985, they accounted for about 2 per cent of the total machine tool stock, rising to 3 per cent by 1987. The NCMT stock of the

Finnish metalworking industry thus compares quite favourably with that in some other countries, though it may be marginally below the level for Sweden, Britain or Japan; it is definitely lagging behind Germany, France or the US in this particular comparison (table 15).

Ideally, the right measure would be to assess the actual production achieved by NCMTs and its share in total engineering output. The rule of thumb of the industry has it that one NCMT produces three to four times the output of a traditional machine tool. Unfortunately, such data are not available for any of the NC-using countries, including Finland.

Industrial robots (IR)

Flexible manufacturing systems (FMS)

These two technologies are associated with the 1980s. Both are important innovations, both are based on microelectronics and numerical control, usually by means of computers, and both have passed the 'take-off' stage and entered a phase of rapid diffusion.

The measurement of this diffusion is difficult in both cases. The time of first adoption is almost impossible to assess because of difficulties of definition: at what point does some ingenious mechanical contraption become a robot? Disregarding the problems of interpreting past data, even counting the present number of robots is not easy. An industrial robot system can serve the whole assembly line of an automobile factory, or just a part of it; or it can help in producing simple metal boxes in a smaller plant. Similarly, a flexible/automatic manufacturing system may cope with the whole production process of a fairly large factory, or may be concerned with only a small part of the same.

This is the problem with defining the 'unit'; any population of robots or FMS will unavoidably include units of different performance capabilities. This must be borne in mind because the diffusion of these new technologies can only be measured by number of units.

The number of robots is heavily influenced by the structure of industry, which varies by country. Robots are particularly well suited to serve certain operations, such as motor vehicle assembly.

The first robots in Finland were installed in 1978. Their number had risen to 418 by 1987; the growth was rapid (51 per cent a year in 1982-5 and 30 per cent a year in 1985-7). In 1982-5 it lagged behind the speed of some other countries - such as France, Japan, and Italy - but moved ahead of others (for example, Sweden and the UK). Although the 1985 comparison in table 16 is not favourable to Finland, there has been another marked increase to 1987; this and the likely further expansion of robot numbers will bring Finland nearer to the higher levels elsewhere.

The data on robots indicate (apart from Japanese leadership in this area) the high technological level of Sweden. The second half of the same table, on FMS, confirms the Swedish progress, even if it is remembered that there are some inherent difficulties in comparing smaller economies with larger ones.

As indicated by the notes to the table, an attempt has been made to reduce those difficulties stemming from the incomparability of the FMS unit. Using the stricter definition (at least four machine tools, etc.), Finland had three FMS in operation in 1986; that secured her a respectable place in the comparison as related to industrial employment, ahead of Italy, France and Belgium, though behind others. Relaxing the definition

Table 16. Industrial robots and flexible manufacturing systems

	Industrial robots			Flexible manufacturing systems		
	1982 thousands	1985	per million industrial employees 1985 a	1984	1986	per million industrial employees 1986
FINLAND	0.07	0.25 0.34b 0.42e	320 440b 540e	1 (4 d)	3 (9 d) (12 de	3.9 (11.6 d) (15.5 d e)
Sweden	1.3	3.4	2640	na	10	7.8
Belgium	0.35	1.0	930	na	4	3.7
France	0.95	5.9	880	na	22	3.3
Germany	3.5	8.8	860	27	50	4.9
Italy	0.7	4.0	580	na	17	2.5
UK	1.15	3.2	410	na	36	4.6
USA	6.25	20.0	670	32	66	2.2
Japan	13.0	70.0	3450	42	102	5.0

Source: (11), Robotics Society in Finland; French Robot Association, Financial Times, 9 October 1987.

(a) Rounded to nearest 10.

(b) 1986.

(c)The systems included are composed of at least four machine tool or robotics subsystems.

(d) These figures are based on different definitions (as used in Finland) to include "more than two NC machines and all the necessary functions for unmanned operations".

(e) 1987.

to at least two NCMTs, etc. raises the numbers of FMS from 3 to 9 in 1986 (and 12 in 1987), but unfortunately, similarly defined data for other countries are not available for international comparison.

Nuclear electricity (NE)

The first commercial nuclear power station was commissioned in 1956 in the UK. Nuclear electricity came rather late to Finland: the first reactor at Loviisa started commercial operations in May 1977; by mid- 1982 four reactors were generating power at two stations. Their combined gross output capacity amounts to 2,160 MW and they supply about 40 per cent of electric power generated in Finland.

Finland has no coal or oil reserves; industrialisation has been based on hydropower and fuelwood, and later on imported coal. The postwar penetration of oil into the rapidly growing Finnish energy market was sudden. In 1973 oil supplied 56 per cent of home energy consumption.

From 1950 to 1973 electricity generation rose sixfold. Hydroelectricity could not cope with growing requirements and by 1973 more than one half of the electric power was produced at thermal stations, burning huge quantities of imported oil.

Between 1973 and 1985 electricity use doubled again (table 17). The further expansion of hydropower was limited and without nuclear power the conventional thermal generating output of the Finnish electricity supply system would have had to have been more than doubled, with a considerable additional burden on the import bill.

There are many factors within a complex system which decide the degree of utilisation of nuclear (or any other) power stations. These vary from country to country; without detailed knowledge it may be misleading to draw any major conclusions from comparisons of this kind. (The very high capital costs of nuclear power stations are of course likely to stimulate their use in any case.) It is nevertheless of interest to point to the data in table 18; the simple facts shown there indicate that the Finnish electricity industry was among the world leaders in this area: the output of the Finnish reactors as related to capacity was one of the highest in the world.

It is interesting to add that the productivity in these terms, i.e. KWh/KW, of the Finnish hydropower stations was also the highest in Europe (table 19); for more precise comparison, allowance must be made for the different hydrological conditions in the various countries.

A relatively new departure in the energy area has been the exploitation on a commercial scale of Finland's huge peat deposits. This was triggered off by the 1973-4 oil price explosion. By the mid-1980s peat production had reached about 4 million tonnes a year, equalling about 1 million tonnes of oil or 1½ million tonnes of coal.(14)

Table 17. Electricity generation in Finland

Million KWh and per cent in total

	1950		1973		1985	
Hydro	3.7	88	10.4	42	12.2	26
Thermal	0.5	12	14.5	58	16.9	36
Nuclear	-	-	-	-	18.0	38
Total	4.2	100	24.9	100	47.1	100

Source: *World Energy Supplies*, UN.

Table 18. Nuclear power: selected indicators

	Nuclear generating capacity, thousand MW 1986	Nuclear electricity as per cent of total generation 1986	Nuclear generation per kW capacity installed[a] kWh/year 1986	Finland = 100 1986	Finland = 100 1982-1986[b]
OECD countries					
Belgium	5.5	67	6762	87	90
Canada	11.2	15	5973	77	76
FINLAND	2.3	38	7792	100	100
France	44.7	70	5401	69	68
Germany FRG	18.9	29	5917	76	88
Italy	1.3	5	6441	83	71
Japan	25.8	25	6448	83	82
Netherlands	0.5	6	7889	101	96
Spain	5.6	29	6412	82	63
Sweden	9.5	50	7086	91	83
Switzerland	2.9	39	7264	93	93
UK	10.2	18	5068	65	97
USA	84.6	17	4894	63	60
Centrally planned economies					
Bulgaria	1.6	30	6860	88	91
Czechoslovakia	2.8	21	5930	76	85
Germany GDR	1.7	10	5962	77	84
Hungary	1.2	26	5668	73	80
USSR	27.7	10	5395	69	73
Yugoslavia	0.6	5	6012	77	76
Other countries					
Argentina	0.9	11	5775	74	64
Brazil	0.6	c	6260	80	82
India	1.2	3	3900	50	46
Korea (South)	5.4	44	4944	63	65
Pakistan	0.1	2	4000	51	31
South Africa	1.8	7	4777	61	56
Taiwan	4.9	44	5246	67	..
World total	273.7	..	5532	71	72

Source: International Atomic Energy Agency, Vienna; World Energy Supplies, UN; Petroleum Economist, November 1987.

(a) Public power stations.

(b) Average of five years.

(c) Less than ½ per cent.

Table 19. Hydropower: generation (KWh/year) per KW capacity installed

	Annual averages	
	KWh/KW/year 1984/5	Installed capacity 000 MW, 1985
Finland	5,081	2.5
	Finland=100	
Sweden	95	13.5
Norway	85	19.4
Portugal	69	3.1
Austria	58	9.6
France	57	20.3
Switzerland	49	10.9
Germany FRG	45	6.0
Spain	45	13.3
Italy	43	15.3

Source: As for table 17.

Note: Outside Europe comparable data vary depending on the geography of the hydropower stations: as related to Finland, the figures for the US are generally markedly lower, for Canada somewhat higher, and in many developing countries, with better endowments for hydro-generation, also higher (for example, Madagascar and Mali in Africa; Honduras, Jamaica and St Vincent in the Caribbean; Bangladesh and Iraq in Asia.

Assessment

An attempt can now be made with a view to somehow summing up the previous brief case studies and thereby assessing the Finnish approach to new technologies. At the risk of repetition, it is advisable at this stage to remember again that

- the present study covered selected technologies;
- in no way can the result therefore correctly represent the whole economy;
- the study of another 'basket' of technologies could yield perhaps quite different conclusions;
- the late introduction (or rejection) of a novel technology may have a very rational justification which can only be ascertained by detailed studies at plant level;
- it follows that the findings should be interpreted with caution;
- nevertheless, the technologies represent activities in a wide range of industries and consequently are likely to have significant indicative value, pointing to the readiness (or otherwise) of Finnish industry and business to innovate, as well as
- this study gives a pointer to the degree and speed of diffusion of (these) new technologies across the economy.

The method applied for the assessment is as follows.

As in the detailed notes on each of the technologies covered, in the summary we concentrate on three aspects. First, how quickly (or slowly) the new techniques were adopted after the innovation at the very first commercial introduction (i.e. the pioneer). This 'Finnish lag', expressed in numbers of years, is compared with the same lag for Sweden and with the average of the four largest European OECD countries.

Secondly, we measure - also in years - the time required to attain two benchmarks of diffusion: a 50 per cent diffusion rate (wherever applicable); and another rate that has been set according to the particular technology and the situation in the industry using the new process. These two measures are assessed for the same three areas, Finland, Sweden and the four large European countries.

Thirdly we compare the Finnish diffusion rate in the most recent years (1985-6) with those in the four European countries and in Sweden. Not all three indicators can be assessed for all technologies covered but the available information is sufficient for the next step, which aims at pulling together the large number of data - presented in table 20 - into a possibly simple quantified form.

Each of the twelve technologies was 'marked' for its attainment in these three areas - the adoption lag, the speed and the level of diffusion - in the simple manner described in the notes to table 20. The marks were then averaged. The message conveyed by the exercise is as follows:

1) Finnish industry was not particularly quick to adopt new technologies. The overall willingness to follow the pioneers rapidly was no better than average; there have been exceptions, involving the immediate introduction of innovations developed elsewhere (for example, in the paper, shipbuilding and brick industries) but these appear to have been balanced by very long lags in other areas.

Table 20. New technologies in Finland (SF)[a]

Tech-nology	Time of adoption: Year and country[a] of innovation	Time of adoption: Adoption in SF	Lag (years) in SF	Lag (years) in 4E[a]	Lag (years) in S[a]	Method[b]	Time (years) to attain 50p.c. diffucision: SF	4E	S	x=	Time (years) to attain x p.c.diffusion: SF	4E	S
BOP	1952 A	1968	16	7	4	A	1	16	23	100[e]	10	20	25
CC	1952 A	1968	16	6	11	A	3	23	18	80	9	26	22
SP	1963 S	1964	1	2	0	A	d	d	d	d	d	d	d
TK	(c)	1943	0	8	5	A	na[a]	22	8	90	40	28	30
FG	1959 UK	1987	28	8	17	A	1	15[f]	1	90	1	28[f]	3
SL	1953 F	1959	6	4	3	B	23	29	25	100	23	NYR[a]	25
GA	1959 UK	1965	6	5	0	A	na	na	3	..	na	na	na
PC	1950 S/UK	1955	5	8	0	A	5	9	10	80	10	13	16
NCMT	1955 US	1962	7	4	4	B	-	-	-	3	25	24	22
IR	na	1978	-	-	-	C	-	-	-	-	-	-	-
FMS	na	1983	-	-	-	C	-	-	-	-	-	-	-
NE	1956 UK	1977	21	5	15	A	-	-	-	-	-	-	-

	Diffusion rate in 1985-86: SF	4E	S	Marks[h] for adoption	Marks[h] for diffusion: speed	85-6 level
BOP	100[e]	100[e]	100[e]	3	1	1
CC	94	75	81	3	1	1
SP	90	90	90	1	1	1
TK	95	90	95	1	2	1
FG	100	95	na	3	1	1
SL	100	49	100	2	1	1
GA	na	na	na	2	..	..
PC	g	g	g	1	1	..
NCMT	3	4 1/2	4 1/2	2	2	2
IR	440	680	2640	..	..	3
FMS	3.9	3.8	7.8	..	..	2
NE	38	31	39	3	..	1
			average:	2.1	1.3	1.4

Notes: Partly estimated.

(a) For symbols of the technologies in col.1, see text. Country codes: SF=Finland; A=Austria; S=Sweden; F=France; 4E=four large European countries (France, W.Germany, Italy and UK) average. "na"=not available. NYR=not yet reached.

(b) Diffusion measured by A=share of new technology in total output; B=share of new productive equipment in total stock; and C=numbers relate to million industrial employees.

(c) Prewar omitted; lag counted from 1943.
(d) Indicators not available; SF in line with S, slightly ahead of 4E.
(e) BOP + electric steel.
(f) OECD countries total.
(g) Not used, see text.
(h) 1=good (leading); 2=average; 3=bad (lagging).

Source: refs 7 to 11 and previous chapters.

2) Once the new technology was adopted in Finland, its spread was rapid - indeed, in many cases faster than in the other countries taken for comparison.

This rapid diffusion invites two comments. First, as already hinted at above, the speed of diffusion is often higher for followers than for pioneers; the Finnish experience supports this finding, which was cautiously presented earlier in this study.

The second comment concerns the nature of diffusion in a small country in contrast to a larger one. There is - for example - only one factory producing flat glass in Finland; in the first year after the adoption of the float technique the diffusion rate reached 100 per cent. Similarly, as soon as one of the few major steelworks was converted to BOP, a very high diffusion rate was registered because of the large share of the innovating plant in total domestic production. Thus, in each of these two industries (glass and steel) the high diffusion rate was the outcome of one major decision, whilst in a larger country, where no one plant accounts for a similarly large proportion of national output, several comparable major decisions are needed to attain the same high diffusion rate.

3) In terms of the recent (1985-6) level of diffusion, Finland is well placed. The use of the selected 'new' technologies is almost universally high. Only in the 'high tech' cases is there some lag. In part this may be due to the nature and pattern of industry in Finland, in comparison with other countries' industrial structure - industries particularly suited to robotics or flexible manufacturing systems (for example, vehicle or aircraft manufacture) carry a smaller weight in Finland than elsewhere . It can also be explained - to some extent - by the role of Finland as a

'follower'; the electronics industry, the backbone of 'high tech', started rather late in Finland but has been picking up, as documented by the trade figures: the ratio of high-tech Finnish exports to high-tech imports rose from 0.18 in 1973 to 0.38 in 1980 and was up again to 0.48 in 1985.[5]

The indicators of high-tech areas included in the earlier parts of this study are perhaps too limited and the actual position may be more favourable than reflected by them. Indeed, the authors of one recent study[15] take the view that whilst the Finnish electronics industry has, in general, been an "intelligent and independent follower", in certain product groups it has in fact been "not a follower but a forerunner". They support this view with a few examples of original innovations by Finnish firms (such as flat display modules, digital telephone switchboards, micro-computers, etc.)

The same paper points to the fairly high (though not exclusive) degree of specialisation reflected by patent statistics: of 416 patents granted to the Finnish electronics industry in 1968-85, 280 (67%) concerned industrial applications and 64 (15%) medical ones. It is probably permissible to conclude that Finnish electronics producers have found suitable niches in which to successfully concentrate their innovative activities.

Whilst all this points to favourable aspects in the development of Finnish 'high-tech' industries in certain areas, it would still appear to be correct to regard the whole of this youngest of industries as somewhat lagging behind the West European average (table 21), although the small size of the country and the specialisation in 'niches' may provide a rational explanation for this apparent lag - which, in any case, is not a unique experience among the comparable smaller countries of Europe.

Table 21. Selected indicators of the electronics/'high tech' industries

	Year	Coverage	Production 'A'	% share	Domestic market 'B'	A : B
United States[a]	1986	electronics	300.6	45	315.3	0.95
Japan[a]	1986	"	147.4	22	82.6	1.78
Western Europe[a]	1986	"	137.2	21	148.7	0.92
Rest of the world[a b]	1986	"	76.4	12	191.5	0.40
World[a b]	1986	"	661.6	100	..	..
for comparison: FINLAND c	1985	'high tech' products	5.0	..	6.3	0.79

(a) Billion (thousand million) US $. Source: ref.16.

(b) Excluding centrally planned countries.

(c) Billion FIM. Source: H.Luukkannen, The Finnish high-tech industry takes off, Kansallis-Osake-Pankki, Economic Review, 2/1987.

Concluding thoughts

In a recent study, the Battelle Institute's Geneva Centre for Applied Economics[16] set up the following classification for the stages of technological potential of countries/companies:

1) Inability to use modern technologies;
2) Ability to adopt modern technologies and reach international quality and performance levels without contributing major new developments;
3) Ability to make good use of technologies developed by others and even to surpass them in terms of innovation and performance;
4) Ability to develop technologies which become the "standard of the world".

Expressing a view of the Finnish industry as a whole leaves one open to the dangers contained in any generalisation. Each branch of the industry operates in particular conditions that are unique to the individual category. Nevertheless, the general picture to emerge from the previous assessment amply justifies the verdict that the Finnish industry can be listed in the third group and some of its branches may qualify for inclusion in the top fourth class.

In general terms, whilst the adoption of major innovations followed in some cases with a considerable time lag (which, however, probably conceals the advantage of avoiding any teething troubles experienced with new techniques), this apparent delay was efficiently balanced by the following rapid diffusion of the 'new' technology.

The Finnish industry, therefore, has certainly shown the "ability to make good use of technologies developed by others"; whether it fits into the second criterion of the definition of the third category mentioned above - "even to surpass them [the originators] in terms of innovation and performance" - is more debatable.

Some branches of Finnish industry may be slipping back into the lower category: they did adopt modern technology and reach international performance levels, but without contributing major new developments.

On the other hand, other Finnish activities are safely in the 'top class', having developed technologies which became world leaders: forestry equipment, papermaking machinery, icebreakers, and even specialised segments of high-tech products all being cases in point.

REFERENCES

(1) T. Myllyntaus, 'The "Finnish model" of technology transfer', Helsinki University, mimeo, 1987.

(2) P. Vartia and S. Vuori, 'Development and technological transformation - the country study for Finland', Discussion paper no. 245, October 1987, ETLA-Helsinki.

(3) D. Senghaas, *The European Experience*. Berg Publishers, Leamington Spa, 1985.

(4) D.S. Landes, *The Unbound Prometheus*, Cambridge University Press, 1969, page 489.

(5) S. Vuori and P. Ylä-Anttila, 'Structural changes in Finnish manufacturing', *Bank of Finland Monthly Bulletin*, December 1987, Helsinki.

(6) T. Balogh and P. Streeten, 'The coefficient of ignorance', *Bulletin of the Oxford University Institute of Economics and Statistics*, vol. 25, May 1963, pp. 99-107.

(7) G.F. Ray, 'The diffusion of new technology', *National Institute Economic Review*, no. 48, May 1969, London.

(8) L. Nabseth and G.F. Ray (eds), *The Diffusion of New Industrial Processes - An International Study*, Cambridge University Press, 1974.

(9) G.F. Ray, 'The diffusion of mature technologies', *National Institute Economic Review*, no. 106, November 1983, London.

(10) G.F. Ray, *The Diffusion of Mature Technologies*, Cambridge University Press, 1984.

(11) G.F. Ray, 'Full circle: the diffusion of technology', NIESR-London, 1988 (forthcoming).

(14) The conversion factors to coal equivalent: 1 tonne of peat = 0.3 tce, 1 tonne of peat briquettes = 0.5 tce.

(15) T. Lemola and R. Lovio, 'Possibilities for a small country in high technology production - the electronics industry in Finland', SITRA-IIASA-TES paper no. 3, 1987, Helsinki.

(16) O. Hieronymi, 'The domestic and external impact of national industrial policies: the example of the electronics industry', Battelle-Geneva, December 1987.

ELINKEINOELÄMÄN TUTKIMUSLAITOS (ETLA)
The Research Institute of the Finnish Economy
Lönnrotinkatu 4 B, SF-00120 HELSINKI Puh./Tel. (90) 601 322
Telefax (90) 601 753

KESKUSTELUAIHEITA - DISCUSSION PAPERS ISSN 0781-6847

No 228 MORTEN JONASSEN - PAAVO SUNI, Real Exchange Rates as Indicators of Purchasing Power Parity. 20.02.1987. 30 p.

No 229 JUHANI RAATIKAINEN, Variability of Exchange Rates under Rational Expectations. 21.02.1987. 25 p.

No 230 TIMO AIRAKSINEN, Talletusten verollistamisen vaikutus pankkien käyttäytymiseen ja kannattavuuteen. 31.03.1987. 21 s.

No 231 JUHA AHTOLA, Error Correction Mechanism: An Economic Interpretation. 01.04.1987. 10 p.

No 232 HANNU TÖRMÄ, Katsaus eräisiin pohjoismaisiin panossubstituutiotutkimuksiin. 01.04.1987. 49 s.

No 233 HANNU TÖRMÄ, Pääoman, työn, energian ja raaka-aineiden substituutio Suomen, Ruotsin ja Norjan tehdasteollisuudessa. 01.04.1987. 35 s.

No 234 DAVID BENDOR, Finnish Price Competitiveness - A Sectoral Review". 04.06.1987. 70 p.

No 235 VESA KANNIAINEN, An Alternative Corporation Tax: Implications for Efficiency of Investment and Valuations of Shares. 03.06.1987. 17 p.

No 236 PEKKA NYKÄNEN, Tehdasteollisuuden ja sen toimialojen kansainvälinen kilpailukyky. 10.06.1987. 75 s.

No 237 JEAN-PIERRE SICARD - VALDEMAR DOS REIS MEIXEDO, "L'Economie Européenne a l'Horizon 1992. 18.06.1987. 74 p.

No 238 PASI AHDE, Measurement of Capacity Utilization in Manufacturing Industry. 18.06.1987. 22 p.

No 239 PEKKA ILMAKUNNAS, On the Profitability of Using Forecasts. 29.07.1987. 9 p.

No 240 ERKKI KOSKELA, Changes in Tax Progression and Labour Supply under Wage Rate Uncertainty. 06.08.1987. 20 p.

No 241 TIMO TERÄSVIRTA, Superiority Comparisons between Mixed Regression Estimators. 14.08.1987. 11 p.

No 242 SYNNÖVE VUORI, Tiedonhankinnan ja -välityksen kehittäminen Elinkeinoelämän Tutkimuslaitoksessa. 17.08.1987. 54 s.

Elinkeinoelämän Tutkimuslaitoksen julkaisemat "Keskusteluaiheet" ovat raportteja alustavista tutkimustuloksista ja väliraportteja tekeillä olevista tutkimuksista. Tässä sarjassa julkaistuja monisteita on rajoitetusti saatavissa ETLAn kirjastosta tai ao. tutkijalta.

Papers in this series are reports on preliminary research results and on studies in progress; they can be obtained, on request, by the author's permission.

0033A/14.04.1988