ETLA
ELINKEINOELÄMÄN TUTKIMUSLAITOS
THE RESEARCH INSTITUTE OF THE FINNISH ECONOMY
Lönnrotinkatu 4 B 00120 Helsinki Finland Tel. 609 900 Telefax 601 753

Keskusteluaiheita - Discussion papers

No. 504

Synnöve Vuori

R&D, TECHNOLOGY DIFFUSION AND PRODUCTIVITY IN FINNISH MANUFACTURING

ISSN 0781-6847

30.08.1994

VUORI, Synnöve, **R&D, TECHNOLOGY DIFFUSION AND PRODUCTIVITY IN FINNISH MANUFACTURING.** Helsinki: ETLA, Elinkeinoelämän Tutkimuslaitos, The Research Institute of the Finnish Economy, 1994. 27 p. (Keskusteluaiheita, Discussion Papers, ISSN 0781-6847; no. 504).

ABSTRACT: The study analyses the use of direct and indirect technology inputs and their effects on productivity developments in Finnish manufacturing industries in the 1980s. Direct technology inputs are equivalent to the firms' own R&D activities. The indirect inputs which are studied are technology embodied in domestic and imported intermediate goods and machinery and equipment, and technological spillovers. The study contains estimates of the most important inter-industry spillovers. The firms' own R&D activities seem to improve total factor and labour productivity. Other technology inputs seem to affect productivity in interaction with R&D. The paper also discusses the potential for technology policies for a small country like Finland. It is concluded that it is very important to promote R&D and technology diffusion simultaneously.

KEY WORDS: technology diffusion, inter-industry technology flows, technology stocks, productivity

VUORI, Synnöve, **R&D, TECHNOLOGY DIFFUSION AND PRODUCTIVITY IN FINNISH MANUFACTURING.** Helsinki: ETLA, Elinkeinoelämän Tutkimuslaitos, The Research Institute of the Finnish Economy, 1994. 27 s. (Keskusteluaiheita, Discussion Papers, ISSN 0781-6847; no. 504).

TIIVISTELMÄ: Raportti on aikaisemmin suomeksi ilmestyneen tutkimuksen englanninkielinen yhteenveto. Tutkimuksessa tarkastellaan välittömien ja välillisten teknologiapanosten käyttöä ja niiden vaikutuksia tuottavuuskehitykseen Suomen teollisuustoimialoilla 1980-luvulla. Välittömillä teknologiapanoksilla tarkoitetaan yritysten omaa tutkimus- ja kehitystoimintaa. Välillisistä teknologiapanoksista tarkastellaan koti- ja ulkomaisiin välituotteisiin sisältyviä teknologiapanoksia sekä ns. tahattomia teknologiavirtoja. Yritysten oma tutkimustoiminta näyttää parantavan toimialoittaista kokonaistuottavuuden ja työn tuottavuuden kehitystä. Muut teknologiapanokset näyttävät vaikuttavan vuorovaikutuksessa T&K-toiminnan kanssa.

ASIASANAT: teknologian diffuusio, toimialojen väliset teknologiavirrat, teknologiavarannot, tuottavuus

YHTEENVETO

Tämä raportti on englanninkielinen yhteenveto aikaisemmin suomeksi ilmestyneestä tutkimuksesta.Tutkimuksessa tarkastellaan välittömien ja välillisten teknologiapanosten käyttöä ja niiden vaikutuksia tuottavuuskehitykseen Suomen teollisuustoimialoilla 1980-luvulla. Välittömillä teknologiapanoksilla tarkoitetaan yritysten omaa tutkimus- ja kehitystoimintaa. Välillisistä teknologiapanoksista tarkastellaan koti- ja ulkomaisiin välituotteisiin ja investointitavaroihin sisältyviä teknologiapanoksia sekä ns. tahattomia teknologiavirtoja (technological spillovers). Välillisten teknologiapanosten käytössä on kyse teknologian diffuusiosta. Tavoitteena on ollut myös tarkastella teknologian diffuusion merkitystä yleisemmin pienen maan ja teknologiapolitiikan kannalta.

Raportti sisältää arviot tahattomista teknologiavirroista Suomen teollisuudessa vuosina 1985 ja 1989. Näiden arvioiden pohjana on käsitys, että samoilla teknologia-alueilla tutkimusta tekevät yritykset hyötyvät tahattomien teknologiavirtojen muodossa eniten toistensa tutkimustuloksista. Tahattomat teknologiavirrat syntyvät siten, että osa tutkimus- ja kehitystoiminnan tuloksista siirtyy myös muiden kuin niiden tuottajien käytettäväksi, ilman että niiden luovuttajat tai lähettäjät olisivat tähän pyrkineet ja että niistä saataisiin jokin vastike. Vuotta 1989 koskevan arvion mukaan merkittäviä tahattomia teknologiavirtoja muille toimialoille tuottavat mm. elektronisten piirien ja tietoliikennevälineiden valmistajat, massan, paperin ja paperituotteiden, puutavaran ja puutuotteiden sekä metallituotteiden valmistajat.

Tulosten mukaan näyttää selvältä, että yritysten oma tutkimustoiminta parantaa toimialoittaista kokonaistuottavuuden ja työn tuottavuuden kehitystä. Muut teknologiapanokset näyttävät vaikuttavan vuorovaikutuksessa oman tutkimuspanoksen kanssa. 1980-luvun alku- ja jälkipuoliskolla eri teknologiapanokset näyttävät vaikuttaneen eri tavoin. Jonkinlaisia viitteitä saatiin siitä, että yritysten oma T&K-toiminta olisi vuosikymmenen loppupuoliskolla alkanut tuottaa parempia tuloksia - parantaa enemmän kokonaistuottavuutta - kuin 1970-luvulla ja 1980-luvun alussa. Tämä on aikaisemmista tutkimustuloksista poikkeava tulos ja merkitsee, että tutkimuspanostus vaatii varsin suurta pitkäjänteisyyttä, ja tulokset näkyvät osittain vasta, kun tutkimuspääomakantaa on kertynyt riittävästi. Toisaalta on muistettava välillisten ja välittömien teknologiapanosten vuorovaikutus: on hyvin ilmeistä, että yksinään ei kumpikaan riitä, vaan ne täydentävät toisiaan.

Raportin lopussa tarkastellaan teknologiapolitiikan mahdollisuuksia pienen ulkomaankaupasta riippuvaisen maan kannalta. Näihin mahdollisuuksiin vaikuttavat koko talouden ja erilaisten instituutioiden toimintakyky sekä toisaalta kauppa- ja kilpailupolitiikan asettamat vaatimukset. Koska pieni maa on erityisen riippuvainen muualla kehitetystä teknologiasta, teknologian diffuusion edistäminen on erittäin keskeistä. Tämän tutkimuksen tulosten perusteella yritysten oman tutkimustoiminnan ja diffuusion vuorovaikutuksen tärkeys ja niiden komplementaarisuus saa voimakasta vahvistusta. Näin ollen molempien samanaikainen edistäminen on Suomen kaltaisen maan etujen mukaista.

Introduction[1]

For firms in a small country it is often crucially important, how well they can use technologies developed elsewhere and adapt them to their own needs. In many industries a substantial part of technological change is received by means of various transactions: new technologies are embodied in capital and intermediate goods which are used in production, or they are utilized by obtaining specific rights to use them, for instance by licence agreements. Technology diffusion can also take place without any transactions and in a more or less organized way, by means of education, training and other learning by doing, and by various kinds of transmission of information and personal contacts. The firms' own R&D activities may be called use of direct technology inputs, and other means of transmission of technology - transactions-based technology use and other technology diffusion - use of indirect technology inputs (see Figure 1). There is a large number of studies made in various countries concerning the effects of R&D activities on the productivity, profitability etc. of firms. Also in Finland the productivity effects of R&D have been studied (e.g. Wyatt 1983, Vuori 1986 and Vuori 1992). In

Figure 1. Sources of technology in output

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

[1] This paper is an English summary version of Vuori 1994b, which, in turn, summarizes the results of Vuori 1991b, 1993 and 1994a. I am grateful to Pekka Ylä-Anttila for helpful comments during the various stages of the research. Financial support from the Technology Development Centre (TEKES) is gratefully acknowledged.

contrast, the effects of indirect technology inputs have not been studied earlier in Finland.

This study analyses the use of direct and indirect technology inputs and their effects on productivity developments in Finnish manufacturing industries in the 1980s. Direct technology inputs are equivalent to the firms' own R&D activities. The indirect inputs which are studied are technology embodied in domestic and imported intermediate goods and machinery and equipment, and technological spillovers. The study contains estimates of the most important inter-industry spillovers. The paper also discusses the potential for technology policies for a small country like Finland.

2 Technology spillovers in Finnish manufacturing

Studies concerning technology spillovers have been reviewed, among others, by Mohnen (1989). He looks at several approaches to measure spillovers. Those studies use either unweighted or in various ways weighted sums of R&D expenditures or patent or innovation flows, or they look at the firms' position in technology space. When unweighted sums are used, it is thought that the technology stock which is available to the firm from outside consists of the R&D stock of all other firms in the industry or other industries of the whole economy. In some other studies cost functions are used to measure spillover effects (see e.g. Bernstein 1989 and Bernstein and Nadiri 1988).

Jaffe's (1986) estimates of technological spillovers are based on the idea that the most important spillovers come from industries which are "neighbours" of the receiving industry in a technological sense. Jaffe uses data on the distribution of patents obtained by the firms across various product groups to assess the technological distance between firms. The same basic idea is applied by Goto and Suzuki (1989), who use data which is in general much more easily available. Instead of firm data on patents they use industry data on the distribution of R&D expenditures across product groups to calculate similar measures of technological distance (P_{ij}) as those used by Jaffe:

$$P_{ij} = F_i F_j' / [(F_i F_j)(F_{ji})]^{½} ,$$

where F_i is a vector describing the technological position of industry i, whose elements F_{im} describe the share of research expenditures invested in technology area m by industry i in its total research expenditures. P_{ij} is thus the correlation of the distribution vectors of research expenditures. The technology flow coming to a certain industry thus consists of the research expenditures of other industries - in Goto's and Suzuki's study electronics-related industries - weighted by the distance indicators.

The same approach is applied in this study to measure inter-industry spillovers in Finnish manufacturing industries. In addition to electronics-related industries, important spillover sources are probably also other parts of the metal products and engineering industries and the chemical industries, which are mentioned e.g. by Geroski (1991) as important technology sources of other industries. The most detailed data available on the R&D expenditures by product group of manufacturing industries are used for 1985 and 1989. For the actual spillover calculations, based on the indicators of technological distance described above, all pairwise correlations of the distribution vectors of research expenditures of industries exceeding 0.1 were taken into account. Even with such a low limit, the number of correlations was, quite naturally, fairly low.

The results of the spillover calculations for 1989 are shown in Appendix table 1. As can be seen from the table, data for other sectors than manufacturing were included in the calculations, since they also contribute to the production of spillovers, and are also important recipients of spillovers. In Appendix table 2 the spillovers have been divided into two categories: spillovers which are "internal" from the point of view of manufacturing, i.e. where both the sender and the receiver of the spillover is a manufacturing industry, and other spillovers. In the latter case, at least one of the counterparts is not a manufacturing industry. Since machinery-related industries are of special interest when technology flows are considered, the industries have been grouped into machinery and vehicles on the one hand and all other industries on the other.

Some of the most important spillovers are shown as Figures 2 and 3, and for comparative purposes the size of each industry's own R&D expenditures are also shown. Of the machinery-related industries the most important senders of spillovers are radio, TV and telecommunication equipment, and other electrical equipment, and of the other manufacturing industries, producers of pulp, paper and paper products, wood and wood products, and metal products.

The comparison of the spillovers in 1985 and 1989 was complicated by the fact that the official R&D data for those years were produced using slightly different industry and product group classifications. As it turned out, a considerable number of business units included in the data were classified into a different industry in those years.This can be seen as an indication of the rapid changes in the activities and proprietorship of the firms. The number of product groups was increased from 51 in the 1985 statistics to 56 in the 1989 statistics, but all the categories for 1989 cannot be directly combined to be in accordance with the 1985 data. Another problem was that the R&D data for 1985 could not totally be divided according to the product group classification, but were partly given for broader categories. Unfortunately, this is especially true for the metal products and machinery product groups, which would have been central for the estimation of inter-industry technology flows.

To be able to compare the spillover figures for 1985 and 1989, the data were aggregated where necessary, and this produced estimates for 30 manufacturing industries, based on 46 product groups. As is to be expected, aggregation conceals information, whereby the spillover estimates for 1989 were reduced, on average by more than a fifth. More seriously, however, the spillover estimates changed so much between these years that some of the changes in classification seem to have been "real" and not just technical. The data for 1989 seem to be more reliable, and thus the comparison of these two years was not quite as meaningful as desired. It may be mentioned, however, that the estimated spillovers for 1985 were on average only about 40 per cent of those for 1989.

Figure 2. Sent and received inter-industry spillovers and R&D expenditures in selected industries in 1989

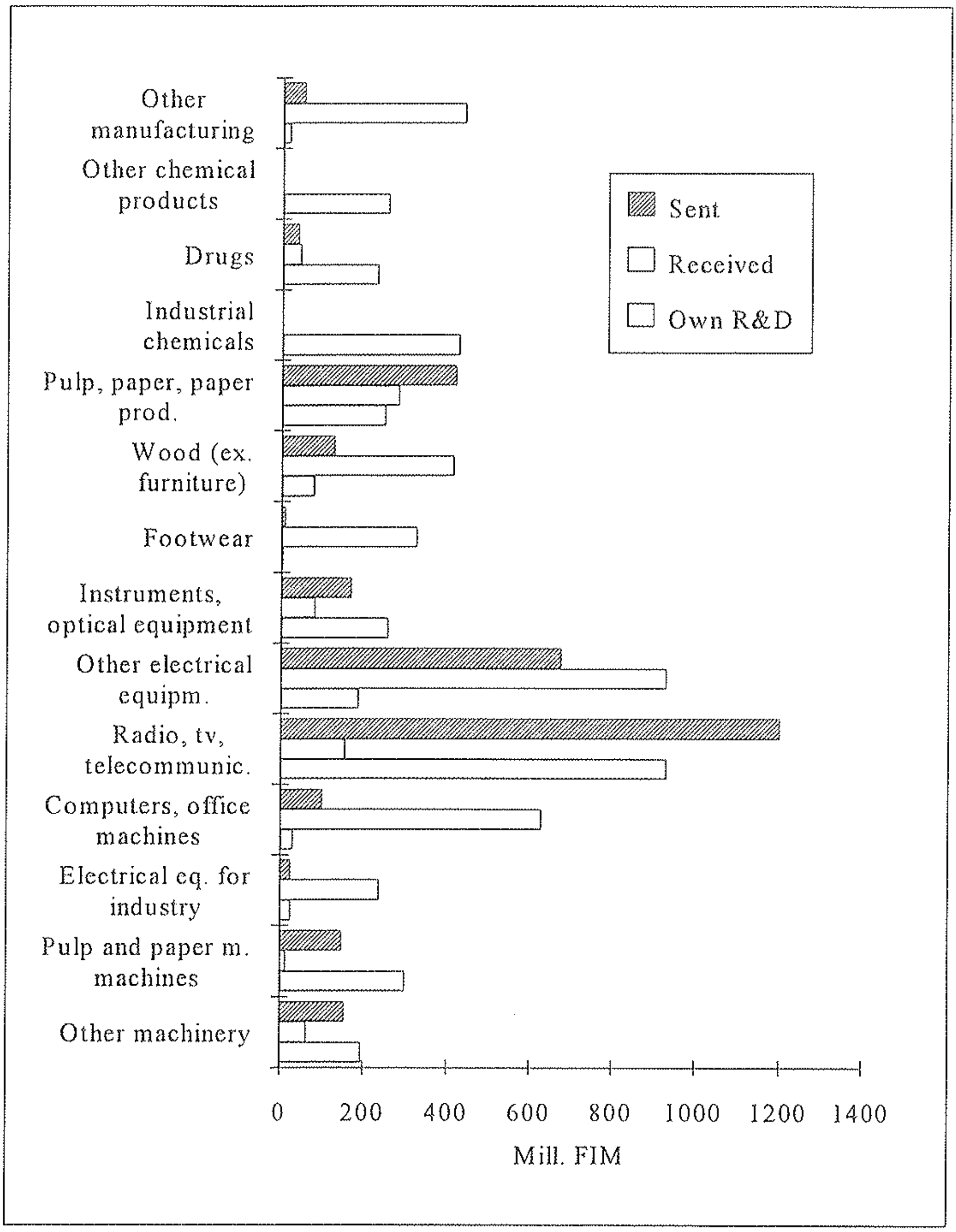
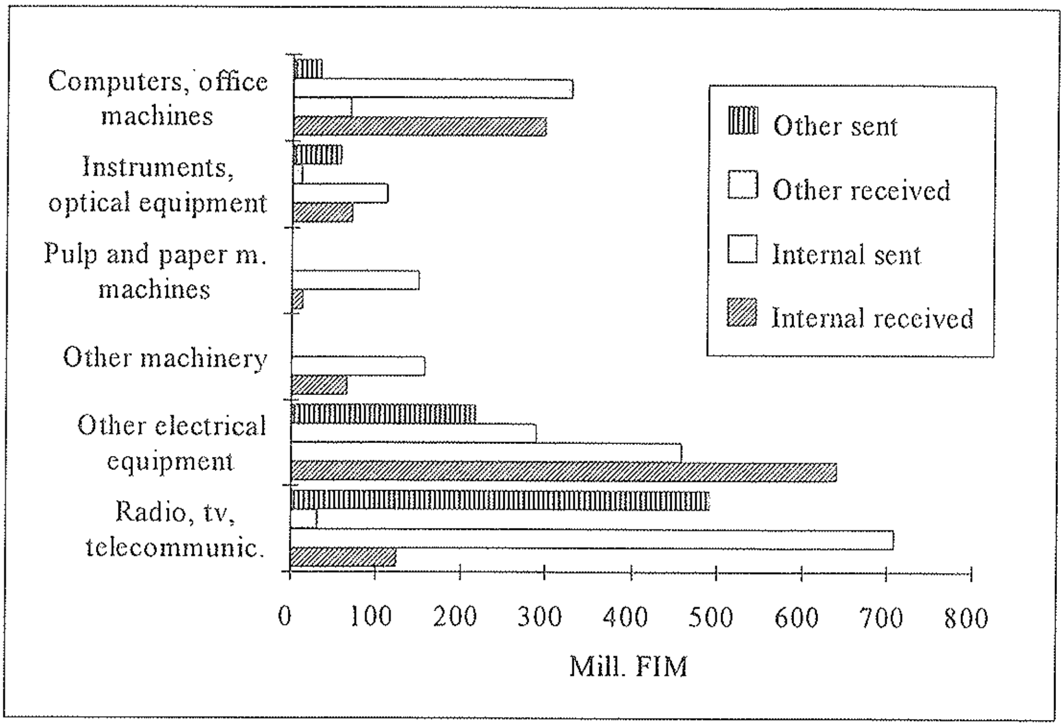


Figure 3. Internal and other spillovers in selected manufacturing industries in 1989



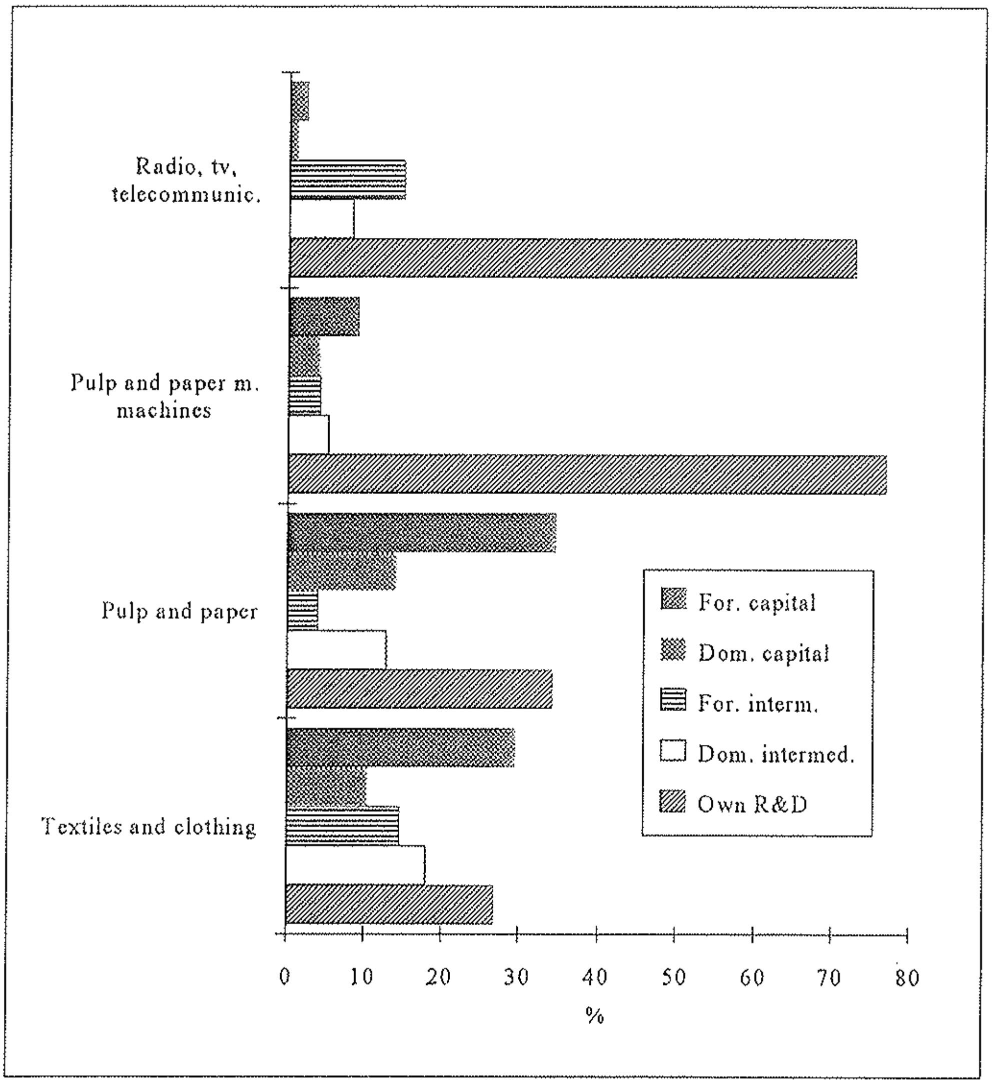
3 Effects of direct and indirect technology inputs on productivity

In this section the following question is addressed: what is the role of the firms' own R&D activities on one hand and of indirect technology inputs on the other for the productivity developmments of manufacturing industries. If the results were the same as in studies which have dealt with other countries, that is, that the effect of purchased inputs would be larger than the effect of R&D, this would have important implications for technology policy.

In the following, the effects of the various technology inputs on both total factor productivity (TFP) and labour productivity are analysed. The technology inputs considered are (see Figure 1 above): the firms' own R&D, technology inputs embodied in domestic and foreign intermediate goods and domestic and foreign capital goods, and technological spillovers.

Several researchers outside Finland have studied the effects of indirect technology inputs especially on the productivity of firms and industries. In these contexts estimates of the magnitudes of the technology inputs embodied in intermediary and investment goods have also been made. The first estimates for Finland have been made recently (Virtaharju and Åkerblom 1993). These estimates, made at Statistics Finland, differ from most other ones i. a. in that they take into account the cumulative nature of technology, that is, technology consists of stocks based on annual flows (R&D expenditures) instead of looking only at those flows. The industry-specific additions to the technology stock consist of weighted annual R&D expenditures of firms. In the method used, every addition to the stock remains in the stock for three years and after that decreases evenly for 7 years. Thus each year's increment in technology affects production for 10 years. The annual depreciation rate is 15 percent (Virtaharju and Åkerblom 1993, p. 12). A similar depreciation rate for calculating technology stocks has been used e.g. by Patel and Soete (1988).

Figure 4. Shares of various technology sources in total technology intensity in selected industries in 1985, %



Source: Virtaharju and Åkerblom 1993

In assessing the total technology used by manufacturing in production Virtaharju and Åkerblom used the stock concept both for the technology consisting of the firms' own R&D and for the technology embodied in investment goods. For estimating the technology embodied in imported goods used in production, data on the R&D intensities of the most important importing countries have been used (for more details, see Virtaharju and Åkerblom 1993). These estimates by Statistics Finland of the direct technology and the technology embodied in investment and intermediary goods, in addition to estimates on spillovers by the author (see section 2 above) are used in this study for analysing the effects on productivity.

According to Virtaharju and Åkerblom, the role of the various technology sources varies considerably across industries. For example, in drugs, electrical equipment for industry and in telecommunication equipment the degree of self-sufficiency in technology is quite high, whereas for instance textiles and wood are highly dependent on technology embodied in machinery and equipment. Roughly speaking, the manufacturing industries can be classified into two categories according to their technology intensity: in the first group of industries total technology intensity is high and also the share of direct (own R&D-based) technology is large, and in the second group total intensity is fairly low and the role of indirect technology is important. Figure 4 shows a few examples of the varying role of the distinct technology sources, excluding spillovers.

The following kind of models were used for the regression analyses:

(1) $$TF = a_0 + \Sigma a_i X_i \text{ , or}$$

(2) $$LPRO = b_0 + \Sigma b_i X_i \text{ ,}$$

where TF is the average change in total factor productivity in the period studied (1980 to 1985 or 1985 to 1991), LPRO is the corresponding average change in labour productivity (volume of output divided by manhours worked, 1980 to 1985 or 1985 to 1990), a_0 and b_0 are constants, the X_i :s are the technology input variables being studied and the a_i :s and b_i :s are the elasticities to be estimated, which describe the effect of the change in the technology input on the change in productivity.

In the simplest case the models contain only one technology input variable, direct technology intensity. This has been the typical approach in previous research, and in this study this kind of models serves as a reference for other models. Indirect technology inputs are contained in the models either as one entity or divided into their compnents. Spillovers are taken in intensity form, that is, they have been divided by the value of production. Models (1) and (2) are fairly similar to those used by Terleckyj (1980). However, Terleckyj divided the technology intensity variable into different components: R&D funded by the private and the public sector, and similarly funded technology inputs purchased from other sectors. In addition he had a few other explanatory factors. Another difference is that flow concepts were used instead of technology stocks.

The same kind of ideas form the basis also of for example Sveikauskas's (1981) and Link's (1983) studies. In one of Goto's and Suzuki's (1989) models industry-based TFP is explained by technology intensity based on firms' own R&D and intensity based on purchased inputs. In another model version an additional explanatory factor is the spill-over intensity from electronics-related industries to other industries. Spillovers were calculated similarly to this study, but not for other industries than electronics-related ones. Indirect technology inputs were not divided into components.

The data concerning direct and indirect technology intensities are from the technology intensity study by Virtaharju and Åkerblom (1993). Technology intensities for 1981 and 1985 were used. Where necessary, industry-specific intensities where aggregated, using each industry's gross outputs as weights. The estimates of technology spillovers are from Vuori (1993) (see section 2 above). The spillovers for 1985 and 1989 were divided by the corresponding inudustry's gross output for the regression models. These variables are subject to more uncertainty than the other technology variables; partly this is because of data and conceptual problems: a stock concept for spillovers seems somewhat difficult to construct, and with the available data practically impossible. Instead, the flow spillovers for 1985 and 1989 are thought to be proxies for the stock concepts for 1981 and 1985, respectively, so as to approach comparability with the other technology variables.

The average annual changes of total factor productivity (TFP) for the periods 1980 to 1985 and 1985 to 1991 were obtained from Statistics Finland for 16 industries. This data was supplemented with labour productivity data, which were calculated for this study. To get comparable estimates for changes in labour productivity, the data from the Finnish industrial statistics had to be partly reprocessed (because of changes in the industry classification). As a result, data for 27 industries were obtained. The productivity data are displayed in Appendix tables 3 and 4.

A brief description of the variables which were used in the regression analyses is given in Table 1. We begin with the results for models with total factor productivity as the dependent variable, and then go on with results for models concerned with labour productivity.

In Table 2 the models T1 to T4 are basic versions of the model for the earlier period (1980 to 1985), with the technology variable components grouped in differing ways. Model T1 corresponds to models typical in the earlier studies; the only explanatory variable is the firms' own R&D effort (dti). In this case most of the variation in TFP is left unexplained. Better results are obtained when other technology variables are added. This means, however, that dti obtains a negative sign, but instead the spillover variable (spq) is positive and significant in models T2 to T4. As it turns out, dti and spq are highly correlated (see Appendix table 5), which can affect the values of the coefficients. Contrary to expectations, also the coefficient for total indirect technology (excluding spillovers), tind, is negative and non-significant.

Table 1. List of variables in the regression analyses

Symbol of variable in tables	Content of variable
tf	average annual change in total factor productivity over a certain period
lpro	average annual change in labour productivity over a certain period
dti	direct technology intensity, technology stock based on firms' R&D expenditures, divided by gross output, per cent
hii	technology intensity of domestic intermediary goods (technology input divided by gross output, per cent)
fii	technology intensity of foreign intermediary goods (technology input divided by gross output, per cent)
hci	technology intensity of domestic capital inputs (technology input divided by gross output, per cent)
fci	technology intensity of foreign capital inputs (technology input divided by gross output, per cent)
spq	technology spillovers received by each industry, divided by gross output, per cent)
tind	hii + fii + hci + fci, total indirect technology intensity (embodied in intermediary and capital inputs)
tii	hii + fii, total technology intensity based on intermediary goods
tci	hci + fci, total technology intensity based on capital inputs
hti	hii + hci, total domestic indirect technology intensity
fti	fii + fci, total foreign indirect technology intensity
timed	dummy variable, 0 in 1980 to 1985, 1 in 1985 to 1990

Since the correlations of the variables pointed to the possibility of their interrelatedness, interaction terms consisting of the product of two correlated variables were added to the models (T5 and T6 in Table 2). However, the results were not clearly better than for the models without interaction terms, and moreover the values of the effects of the variables concerned could not be specified because of partly nonsignificant coefficients of the components.

In Table 3 regression results for the latter period (1985 to 1991) are reported. Here the results are different from those concerning the earlier period. For this period the coefficient of the firms' own research inputs is positive and almost invariably significant in the various model versions. Instead, the coefficients of several other technology variables are negative and in some cases significant (for instance, tind in model t8). Since also in this period some of the variables are highly correlated (see Appendix table 5), models T11 tro T13 contain interaction variables. These models yield mostly significant, although partly negative coefficients. The reliability of these results is, however, reduced because of the fairly high number of explanatory variables in relation to the number of observations. Nevertheless, the adjusted R^2 is in each case reasonably high.

For the latter period model T13 thus seems to yield the "best" results, though with some reservations. The coefficient for the interaction term hii*fii is nonsignificant. It should also be noted that when looking at the coefficients of the basic variables, also the effects of the interaction terms should be taken into account. Thus the value of dti is (0.306 + 0.271 spq), or about 0.702 at the mean value of spq. Similarly the value of spq at the mean values of the variables contained in the interaction terms is (5.882 + .271 dti - 4.709 hii - 3.640 fii + 1.334 hii*fii) = about - 0.316. Thus the effect of the firms' own reasearch input would be positive and that of spillovers negative. The values of the coefficients of tind and its components cannot be specified because of partial nonsignificance. It thus seems that there are interaction effects between the technology variables but they are perhaps more complicated than is assumed when using models with this kind of specifications. The most reliable result seems to be that the firms' own research activities affect positively their total factor productivity. The other technology variables affect it in a way which is so far left unspecified.

To find out whether the results would be partly due to the relatively small number of observations, the data for the two periods were combined, using a time dummy variable to imply the possibility of a level difference between the periods (with the value 0 for the earlier period and 1 for the latter one). The results are reported in Appendix table 6. Adding the number of observations does not seem to improve the results, which generally speaking are weaker than those for the latter period alone. The time dummy variable is not significant, which implies that the difference between the periods is not of the kind assumed. In these models also the most clear effect is of the variable dti.

The differences in the results concerning the two subperiods point to the possibility that the variable concerning technology spillovers would not sufficiently well describe the phenomenon concerned, and especially not its changes over time. As was noted in section 2, the comparability of this variable in 1985 and 1989 may not be sufficient because of changes in industry classifications. In addition, flow-type variables were used as approximations for stock-type ones (see above), which may also lead to incorrect measures. Therefore, in future studies the spillovers should be estimated more accurately.

Table 2. Estimation results for models with average annual changes (%) in total factor productivity in 1980 to 1985 as the dependent variable

Variable	Model T1	Model T2	Model T3	Model T4	Model T5	Model T6
Constant	2.2478	3.8300	3.3721	3.3945	3.1941	3.0997
	(4.61)	(3.23)	(2.81)	(2.63)	(2.41)	(2.47)
dti81	0.1398	-0.2017	-0.2777	-0.3034	0.2154	0.5646
	(1.68)	(-0.96)	(-1.32)	(-1.22)	(0.51)	(1.19)
tind81		-0.5007				
		(-1.28)				
spq85		0.6189	0.8177	0.8334	0.1703	-0.6114
		(1.99)	(2.44)	(2.28)	(0.33)	(-0.80)
tii81			-0.9126			
			(-1.88)			
tci81			0.2291			
			(0.35)			
hii81				-1.2075	-1.5702	-1.9438
				(-1.17)	(-1.46)	(-1.84)
fii81				-0.8544	-0.6176	1.8630
				(-1.34)	(-0.97)	(0.96)
hci81				-3.7700	-4.1688	-3.7797
				(-1.27)	(-1.48)	(-1.41)
fci81				1.8805	2.0958	1.8031
				(1.42)	(1.64)	(1.47)
dti*fii					-0.5627	-1.6892
					(-1.75)	(-1.89)
dti*spq						0.2573
						(1.34)
spq*fii					0.8238	0.6352
					(1.62)	(1.27)
Adjusted R^2	0.109	0.2553	0.3027	0.3117	0.3864	0.4496
SEE	1.58	1.44	1.39	1.39	1.31	1.24
F statistic	2.83	2.71	2.63	2.13	2.18	2.36
Number of observations	16	16	16	16	16	16

t statistics in brackets below the coefficients

Table 3. **Estimation results for models with average annual changes (%) in total factor productivity in 1985 to 1991 as the dependent variable**

Variable	Model T7	Model T8	Model T9	Model T10	Model T11	Model T12	Model T13
Constant	1.0106	2.5182	2.7078	2.9897	-3.6288	2.3722	2.5628
	(2.32)	(2.46)	(2.30)	(1.95)	(-0.79)	(1.18)	(1.92)
dti85	0.1952	0.2585	0.2449	0.2374	0.6594	0.3001	0.3062
	(3.19)	(3.85)	(3.12)	(2.69)	(2.16)	(1.68)	(1.91)
tind85		-0.4287					-0.5761
		(-1.78)					(-1.83)
spq89		0.0154	0.0121	0.0100	13.5768	6.138	5.8821
		(0.44)	(0.33)	(0.25)	(2.21)	(1.82)	(2.27)
tii85			-0.3617			-0.3309	
			(-1.18)			(-0.18)	
tci85			-0.5615			-0.6302	
			(-1.30)			(-1.20)	
hii85				-0.5760	5.4306		
				(-0.64)	(1.23)		
fii85				-0.2544	1.0711		
				(-0.46)	(0.50)		
hci85				0.1469	-1.1203		
				(0.05)	(-0.42)		
fci85				-0.9138	-0.9344		
				(-0.67)	(-0.65)		
dti*spq					0.6118	0.2825	0.2706
					(2.20)	(1.76)	(2.17)
hii*fii					-1.1733	0.2862	0.4259
					(-0.78)	(0.27)	(1.52)
hii*spq					-11.4255	-4.9138	-4.7091
					(-2.20)	(-1.87)	(-2.37)
fii*spq					-7.4306	-3.8116	-3.6401
					(-2.17)	(-1.66)	(-2.04)
hii*fii*spq					2.7563	1.4014	1.3337
					(2.21)	(1.73)	(2.25)
Adjusted R^2	0.38	0.46	0.42	0.3	0.51	0.5	0.57
SEE	1.36	1.28	1.32	1.45	1.21	1.23	1.14
F statistic	10.23	5.22	3.67	2.06	2.41	2.66	3.48
Number of observations	16	16	16	16	16	16	16

t statistics in brackets below the coefficients

It is also not quite clear how long time lags there are between technology inputs and productivity. Although we are using cross sectional data, the choices concerning the periods for which the data were taken may affect the results. However, it was not possible in this study to analyse the effect of slightly different time periods on the results.

The results also bring up the issue of whether there would be a real and significant change causing the difference between the results concerning the earlier and latter half of the 1980s. According to the results there were quite clear indications of a positive effect of the firms' own R&D on TFP in the latter period. This result differs from earlier results for Finland, according to which for the period 1964 to 1983 the rates of return on R&D were low or could not be specified (e.g. Vuori 1992). The newer results were obtained for a different time period, and also using cross-sectional data instead of time series. However, they indicate that R&D investments, which grew rapidly in the 1980s would finally have become productive in the late 1980s. If this is true, it is another proof of the cumulative character of the outcome of technology investments.

Next, the effects of the technology variables on changes in labour productivity were analysed. Table 4 contains regression results for both the earlier (1980 to 1985) and the latter peirod (1985-1990). In Table 5 the data for the two periods have been combined. Since the spillover variables were not estimated for a similar industry classification which was used in this connection, this variable was left out from these analyses.

In the earlier period the coefficient of the R&D variable (dti) was clearly significant, and the variables for domestic intermediate technology inputs and foreign capital inputs produced coefficients which were significant at the 1 per cent level. Adding interaction terms in the same way as for the models explaining TFP did not seem to essentially improve the models.

The results for the latter period were clearly weaker than those for the earlier one. Not even the R&D variable obtained a significant coefficient. The results may be due to many factors, but one possibility seems to be that the adjustments in the industry classifications in the productivity calculations may not have been sufficiently detailed to allow possible industry-specific effects to be found from the data. The results for the combined data were rather weak, and also here the time dummy was not significant. The domestic intermediate inputs variable seems to be more important than the R&D variable. However, the results seem to be fairly sensitive to the model specifications used.

In these models having changes in labour productivity as the dependent variable, a considerable part of the variation in this variable was left unexplained. Therefore, labour productivity changes should be explained by additional variables. It is probable that a capital input variable would be an important explanatory variable. The results are

Table 4. **Estimation results for models with average annual changes (%) in labour productivity in 1980 to 1985 (models L1 to L3) or 1985 to 1991 (models L4 and L5) as the dependent variable**

Variable	Model L1	Model L2	Model L3	Model L4	Model L5
Constant	0,9044	4.2155	4.6374	4.9003	9.2154
	(0,44)	(1.26)	(1.51)	(1.48)	(2.22)
dti81(85)	0.1775	0.2674	0.2493	0.0190	0.3615
	(2.01)	(2.11)	(2.18)	(0.22)	(1.12)
hii81(85)	2.0790	2.0496	2.2844	1.6672	
	(1.66)	(1.43)	(1.81)	(1.50)	
fii81(85)	-0.5035	-0.1124	-0.5178	-0.4537	
	(-1.07)	(-0.07)	(-0.39)	(-0.90)	
hci81(85)	-5.7324	-13.9989	-15.0722	6.6025	
	(-1.06)	(-1.41)	(-1.62)	(0.85)	
fci81(85)	3.5861	-0.0838	-0.3926	-3.0036	
	(1.56)	(-0.02)	(-0.12)	(-0.83)	
hci*fci		7.6391	8.4169		
		(1.04)	(1.23)		
fii*fci		-0.5258	-0.4775		
		(-0.60)	(-0.56)		
dti*fii		-0.0134			
		(-0.38)			
hti85					-1.8501
					(-0.76)
fti85					-2.9010
					(-2.08)
dti*hti					-0.1908
					(-1.24)
hti*fti					1.5211
					(1.79)
Adjusted R^2	0.1644	0.1635	0.2011	-0.0220	0.0944
SEE	2.7458	2.7473	2.6848	4.5095	4.2450
F statistic	2.0229	1.6352	1.9352	0.8882	1.5420
Number of observatios	27	27	27	27	27

t statistics in brackets below the coefficients

Table 5. **Estimation results for models with average annual changes (%) in labour productivity in 1980 to 1985 or 1985 to 1991 as the dependent variable and combined periods**

Variable	Model L6	Model L7	Model L8	Model L9
Constant	3.1410	3.1064	2.1308	5.8001
	(1.88)	(1.88)	(1.00)	(2.53)
timed	0.3222			
	(0.26)			
dti	0.0761	0.0778	0.2672	0.5446
	(1.27)	(1.32)	(1.63)	(2.78)
fii	-0.2624	-0.2829		
	(-0.80)	(-0.90)		
hii	1.6083	1.6841		
	(2.10)	(2.39)		
hci	-0.7970	-0.3441		
	(-0.17)	(-0.08)		
fci	0.5938	0.5213		
	(0.29)	(0.26)		
tii			1.0359	
			(1.55)	
tci			1.1387	
			(1.04)	
dti*tii			-0.0258	
			(-1.11)	
dti*tci			-0.0676	
			(-0.80)	
tii*tci			-0.2888	
			(-1.47)	
hti				-0.4478
				(-0.32)
fti				-2.3009
				(-2.16)
dti*hti				-0.2124
				(-1.96)
dti*fti				-0.0154
				(-0.70)
hti*fti				1.2540
				(2.13)
Adjusted R^2	0.0537	0.0720	0.0370	0.1691
SEE	3.7031	3.6670	3.7356	3.4700
F statistic	1.5013	1.8230	1.3395	2.7976
Number of observations	54	54	54	54

t statistics in brackets below the coefficients

probably also affected by the fact that the models do not contain the spillover variable. However, as a very preliminary result it could be concluded that at least the firms' own R&D and the technology inputs embodied in domestic intermediate inputs would affect labour productivity positively.

To sum up, the various technology inputs seem to affect both total factor productivity and labour productivity in a different way in the early and the late 1980s. According to the results TFP is more strongly affected in the earlier period by spillovers and in the latter period by the firms' own R&D activities. Depending on the model specification, some of the technology variables yielded negative coefficients. However, interpretation of the results is not easy because of the interrelationships between some of the explaining variables. Therefore, the magnitude of the impact of a single variable cannot be estimated very accurately. It seems clear, however, that the firms' own R&D has a positive effect on both the TFP and the labour productivity of manufacturing industries. Moreover, it is highly important to take the other technology inputs into account, since they seem to affect productivity in interaction with R&D. Possibly positive impacts were also partly found for spillovers and technology embodied in domestic intermediate goods and foreign capital goods. However, the interrelatedness of the various technology components seem to be fairly complicated. A more detailed analysis should be done later on.

4 Technology policy and small open economies

As a consequence of rapid technological change and enormously fast increase of the amount of information available, firms on one hand and countries on the other, have become more and more dependent on technologies developed elsewhere. According to one estimate (Steed 1989) most industrial countries, except the United States and Japan, only produce about one fifteenth or twentieth of the technologies they use. It has especially become impossible for small countries highly dependent on foreign trade to develop anything like a substantial share of the technologies they need.

For the majority of OECD countries the payments for imported technology are one- to twofold as compared to the corresponding receipts for technology exports. According to this measure for the worst-performing countries (Austria, Finland, Spain and Portugal) technology imports are three to seven times technology exports (for Finland about 7 times in 1990). Technological self-sufficiency can also be described by means of another indicator, which states how large the payments for technology imports are in comparison to the R&D expenditures of the business sector. Seen from this point of view Finland performs clearly better. While this ratio was between 0,1 and 0,4 for most OECD countries in 1990, for Finland it was 0,19. According to this indicator a much higher dependency on imported technology is found for Belgium, Spain and Portugal, where the payments for imported technology were almost as large or larger than the

R&D of the business sector (Industrial policy in OECD countries, Annual Review 1993 pp. 128-129).

Dependency on technology developed elsewhere can also be described by the relative magnitudes of the direct and indirect technology inputs that are used by the firms. According to Virtaharju and Åkerblom (1993), the share of direct technology of Finnish manufacturing firms, which consists of their own R&D expenditures, in their total technology use was during the 1980s at least a half, and increasing. The share of technology embodied in physical capital inputs in total technology was slightly over 20 per cent, about the same as the share of technology embodied in intermediate inputs. This means that the firms' own resarch inputs are, nevertheless, a crucial source of technology.

Still in the early 1980s technology policy was in most industrial countries mostly looked at separately from general economic policies. It was also typical to focus on the R&D investments of firms as well as on innovations, whereas the diffusion of innovations did not receive much attention. The arguments which have been presented for treating diffusion and R&D differently have not, however, been very convincing. It has thus become more usual to claim that when selecting means to promote diffusion and R&D, they should be looked at simultaneously (see e.g. Freeman & Soete 1986, pp. 846-852).

Imperfect appropriability is a central characteristic of technological information. This has both positive and negative consequences for firms. On one hand, they can profit from the research results of others all the more with less perfect appropriability. The other side of the coin is of course that whether they want to or not, they also give away some of their own results to others. When a substantial amount of research results is tranferred in the form of technological spillovers from one country to another, the question arises, what is the role of national technology policies? Is it sensible, for instance, for the government to subsidize national research and development projects, if it is to be expected that a large share of the utility from research results "spills over" abroad without any incomes being generated?

Small open economies are in a position which is clearly different from that of larger industrial countries as far as spillovers are concerned (Griliches 1990). If a large share of the goods produced in a small country are exported, it is probable that also a substantial share of the generated technological change leaks abroad. In this case it is not clear why the government of such a country should use tax revenues to subsidize R&D, since a large share of the benefits would be gained by the citizens of other countries. However, there is also an inward flow of technology, which can only be utilized with a large enough own competence. This can only be created with large enough investments in education and the firms' own research, which normally requires also investments by the public sector.

According to Teece (e.g. 1986), if intellectual property rights are not sufficiently well protected, the innovating firm and country must maintain well-developed complementary assets (for instance, production and marketing) to fully benefit from innovation-related spillovers. Protection of intellectual property is also central, but not always possible. This means that the strategies of firms and political decision-makers are crucial for how the benefits from innovations are distributed worldwide. To make sure that it is mostly domestic and not foreign assets that benefit from the externalities flowing to the complementary assets, it is important to strengthen the infrastructure supporting those assets. Otherwise the returns from innovations may be mostly received by imitators and other competitors, or by the owners of specialized resources (see Teece 1986).

Despite the fact that state subsidies to industry are generally feared to distort competition both nationally and internationally, the subsidies are quite substantial in most industrial countries, although their total amount decreased in the late 1980s in the OECD area (Industrial policy in OECD countries, Annual Review 1992). Subsidies to promote technological change have, however, been looked at with a more positive attitude for instance within the European Union than industrial subsidies in general (see e.g. Fölster 1991), i.a. because they are seen to promote positive structural change.

The production of innovations and maintaining competitiveness require more and more co-operation between firms. This may seem to be in conflict with the principles of competition policy. In countries with strong antitrust regulations and traditions (the U.S. for example), encouraging co-operation of firms by political means is still often resisted. In general, however, various networks consisting of firms, universities and research institutes are seen as important means of successful research activities (e.g. Teece 1991).

To sum up, the potential for technology policy is influenced by both demand and supply conditions of the economy as well as by the functioning of social institutions. Technology is increasingly global, and small countries are especially dependent on the technologies developed by others. From this follows on one hand the need to develop one's own compentence to be able to profit maximally from research results produced elsewhere, and on the other hand the need to find protection from too extensive transfer of one's own research results to the benefit of others.

For a small country advancing technology diffusion is at least as important if not more important than supporting the production of new innovations. However, when designing technology policy also trade and competition policy considerations have to be taken into account. It is clear that here one has to find a balance between factors working in opposite directions. For firms it is central to develop their own strengths and complementary assets and to use the potential for cooperation with other firms and research institutes. On the basis of the results of this study the importance of the interaction of the firms' own R&D and technology diffusion as well as their complementarity is strongly confirmed. Thus, promoting both of them simultaneously is clearly in the interests of a small country such as Finland.

References

Bernstein, J.I. (1989). The structure of Canadian inter-industry R&D spillovers, and the rates of return to R&D, Journal of Industrial Economics, Vol. XXXVII, No.3, pp. 315-328.

Bernstein, J.I. and Nadiri, M.I. (1988), Interindustry R&D spillovers, rates of return, and production in high-tech industries, American Economic Review, AEA Papers and Proceedings, Vol. 78, No. 2, May, pp. 429-434.

Davis, L.A. (1988), Technology intensity of U.S., Canadian and Japanese manufactures output and exports, U.S. Department of Commerce, International Trade Administration, Staff report, June.

Freeman, C. and Soete, L. (1986), Innovation diffusion and employment policies, Richerche Economiche, Anno XL, Nro 4, Ottobre-Dicembre, pp. 836-854.

Fölster, S. (1991), Innovationsstöd till företag - stimulans eller slöseri? Ekonomisk Debatt, 1/91, s. 18-28.

Geroski, P.A. (1991), Innovation and the sectoral sources of UK productivity growth, The Economic Journal, Vol. 101, No. 409, November, pp. 1438-1451.

Goto, A. and Suzuki, K. (1989), R&D capital, rate of return on R&D investment and spillover of R&D in Japanese manufacturing industries, Review of Economics and Statistics, Vol. LXXI, No. 4, November, pp. 555-564.

Griliches, Z. (1990), Econometric estimates of R&D returns: Measurement problems, results, and policy implications. Technology and investment, Conference arranged by The Royal Swedish Academy of Engineering Sciences (IVA) and The Swedish Ministry of industry in cooperation with OECD, 21-24 January, 1990, Stockholm (conference paper).

Industrial policy in OECD countries (1992), Annual review 1992, Paris: OECD.

Industrial policy in OECD countries (1993), Annual review 1993, Paris: OECD.

Jaffe, A.B. (1986), Technological oppportunity and spillovers of R&D: Evidence from firms' patents, profits, and market value, American Economic Review, Vol. 76, No. 5, December, pp. 984-1001.

Kendrick, J.W. and Vaccara, B.N. (eds.)(1980), New developments in productivity measurement and analysis, NBER Studies in income and wealth, Volume 44. Chicago and London: The University of Chicago Press.

Link, A.N. (1983), Inter-firm technology flows and productivity growth, Economics Letters, Vol. 11, pp. 179-184.

Mohnen, P. (1989), New technologies and inter-industry spillovers, OECD International seminar on science, technology and economic growth, Paris, June 5-8, 1989. OECD, Directorate for Science, Technology and Industry, DSTI/SPR/89.7, WS/II/III.2, Paris 1989.

Patel, P. and Soete, L. (1988), Measuring the economic effects of technology, Paris: OECD, STI Review, No. 4, December.

Steed, G.P. (1989), Not a long shot. Canadian industrial science and technology policy, Summary of Background Study 55, Science Council of Canada, July.

Sveikauskas, L. (1981), Technological inputs and multifactor productivity growth, Review of Economics and Statistics, Vol. LXIII, No. 2, May, pp. 275-282.

Teece, D.J. (1986), Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy, Richerche Economiche, Anno XL, Nro 4, Ottobre-Dicembre, pp. 607-643.

Teece, D.J. (1991), Technological development and the organisation of industry, in: Technology and productivity, The challenge for economic policy. The Technology Economy Programme. Paris: OECD.

Teollisuustilasto 1980, osa 1 (1982), Helsinki: Tilastokeskus, SVT XVIII A:101.

Teollisuustilasto 1985, osa 1 (1987), Helsinki: Tilastokeskus, SVT XVIII A:106.

Teollisuuden vuosikirja 1990, osa 1 (1990), Helsinki: Tilastokeskus, SVT, Teollisuus 1990:16.

Teollisuuden vuosikirja 1992, osa 1 (1992), Helsinki: Tilastokeskus, Teollisuus 1992:7.

Terleckyj, N.E. (1980), Direct and indirect effects of industrial research and development on the productivity growth of industries, in: Kendrick and Vaccara (eds.) (1980), pp. 359-386.

Tiede ja teknologia 1989 (1990), Helsinki: Tilastokeskus, SVT, Koulutus ja tutkimus 1989:24.

Tutkimustilastot: Yrityssektorin tutkimustoiminnan menot tuoteryhmän mukaan, vuodet 1985, 1987 ja 1989. Tilastokeskus, Helsinki.

Virtaharju, M. and M. Åkerblom (1993), Technology intensity of Finnish manufacturing industries, Helsinki: Statistics Finland (Tilastokeskus), SVT, Science and Technology 1993:3.

Vuori, S. (1986), Returns to R&D in Finnish and Swedish manufacturing industries, helsinki: ETLA (The Research Institute of the Finnish Economy), Discussion Papers No. 203.

Vuori, S. (1988), Total factor productivity and R&D in Finnish, Swedish and Norwegian Manufacturing Industries, 1964 To 1983, Helsinki:. ETLA (The Research Institute of the Finnish Economy), Discussion Papers No. 257.

Vuori, S. (1991A), Returns to R&D in Nordic manufacturing industries, 1964 to 1983, Helsinki: ETLA (The Research Institute of the Finnish Economy), Discussion Papers No. 357.

Vuori, S. (1991b), Teknologiapanosten vaikutukset ja teknologian diffuusio: kirjallisuuskatsaus, Helsinki: ETLA, Elinkeinoelämän Tutkimuslaitos, Keskusteluaiheita No. 382.

Vuori, S. (1992), R&D, technology diffusion and productivity performance in Finnish manufacturing industries, in: Vuori, S. and Ylä-Anttila, P. (eds.), Mastering technology diffusion - The Finnish experience, Helsinki: ETLA, The Research Institute of the Finnish Economy, Series B 82.

Vuori, S. (1993), Tahattomat teknologiavirrat Suomen teollisuudessa. Helsinki: ETLA, Elinkeinoelämän Tutkimuslaitos, Keskusteluaiheita No. 443.

Vuori, S. (1994a), Yritysten ja toimialojen väliset teknologiakytkennät Suomen teollisuudessa, Helsinki: ETLA, Elinkeinoelämän Tutkimuslaitos, Keskusteluaiheita No. 477.

Vuori, S. (1994b), Tutkimuspanostus, teknologian diffuusio ja tuottavuuden kehitys Suomen teollisuudessa, Helsinki: ETLA, Elinkeinoelämän Tutkimuslaitos, Sarja C 65.

Vuori, S. and Vuorinen, P. (1994), Explaining technical change in a small country. The Finnish national innovation system, Heidelberg/New York: Springer Verlag, in association with ETLA, Helsinki.

Wyatt, G. (1983), Multifactor productivity change in Finnish and Swedish industries, 1960 to 1983, Helsinki: ETLA, The Research Institute of the Finnish Economy, Series B No. 38.

Appendix table 1. R&D expenditures, sent and received spillovers by inudstries in 1989 (1000 FIM)

a. Machinery and vehicles			
	Own R&D	**Received spillovers**	**Sent spillovers**
28. Other machinery	195 495	65 578	156 767
29. Machines for agriculture	48 185	-	-
30. Metallurgical machines	33 322	23 475	9 600
32. Machines for construction and	73 518	9 382	7 771
33. Pulp and paper making machines	299 460	13 003	149 655
34. Other machines for industry	26 019	238 308	25 331
35. Computers and office machines	31 493	628 316	102 366
36. Radio, TV, telecommunication	932 433	156 246	1 200 591
38. Electrical equipment for industry	186 879	930 682	675 394
39. Household machinery and	10 721	38 739	1 144
40. Instruments, optical instruments etc.	256 327	83 339	170 311
41. Ships	91 691	-	-
43. Automobiles	53 657	35 360	34 750
44. Aircraft	25 628	-	-
46. Other transport equipment	22 148	-	-
TOTAL (a)	2 286 976	2 222 428	2 533 680
b. Other than machinery and vehicles			
	Own R&D	**Received spillovers**	**Sent spillovers**
1. Agriculture, fishing and trapping	13 400	37 138	1 850
2. Mining	10 120	58 761	4 229
3. Food	169 850	-	-
4. Beverages	79 420	5 283	14 898
5. Tobacco	2 296	995	2 083
6. Textiles	28 165	14 898	5 283
7. Clothing	1 517	15 248	569
8. Leather	1 097	2 083	995
9. Footwear	3 811	324 245	9 008
10. Wood and wood products	80 462	413 268	129 099
11. Pulp, paper and paper products	248 823	280 629	417 933
12. Printing and publishing	6 147	-	-
13. Furniture	22 494	28 440	9 028
14. Industrial chemicals	426 347	-	-
15. Drugs	230 875	45 767	41 223
16. Other chemical products	255 878	-	-
19. Rubber products	28 969	623	4 738
20. Plastic products	54 599	35 103	48 063
21. Glass and glass products	8 157	2 880	903
23. Other non-metallic mineral	140 607	9 953	76 092
24. Ferrous metals	88 763	31 673	47 616
25. Non-ferrous metals	10 763	112 318	4 494

26. Fabricated metal products	81 483	150 638	108 435
47. Sporting and athletic goods	6 540	2 999	2 327
48. Other manufacturing products	17 838	439 277	54 467
49. Energy and water supply	247 024	-	-
50. Construction	46 440	17 331	5 724
51. Trade, hotels and restaurants	54 794	718 723	134 701
53. Communication	83 352	94 577	8 454
54. Computer and data processing	129 708	42 329	100 202
55. Services to business	363 164	206 727	1 258 262
56. Public administration, other	268 979	254 412	544 389
TOTAL (b)	3 211 882	3 346 318	3 035 065
TOTAL (a+b)	5 498 858	5 568 746	5 568 745

Appendix table 2. Internal and other spillovers by industries in 1989 (1000 FIM)

a. Machinery and vehicles	Internal spillovers		Other spillovers		**Total**	
	Received	Sent	Received	Sent	Received	Sent
28. Other machinery	65 578	156 767	-	-	65 578	156 767
29. Machines for agriculture	-	-	-	-	-	-
30. Metallurgical machines	23 475	9 600	-	-	23 475	9 600
32. Machines for construct. & mining	9 382	7 771	-	-	9 382	7 771
33. Pulp and paper making machines	13 003	149 655	-	-	13 003	149 655
34. Other machines for industry	200 020	22 587	38 288	2 744	238 308	25 331
35. Computers and office machines	299 078	68 640	329 238	33 726	628 316	102 366
36. Radio, TV, telecommunic. equipm.	124 474	709 209	31 772	491 382	156 246	1 200 591
38. Electrical equipment for industry	641 034	458 280	289 648	217 114	930 682	675 394
39. Household machinery and equipm.	-	-	38 739	1 144	38 739	1 144
40. Instruments, optical instruments etc.	70 991	112 548	12 348	57 763	83 339	170 311
41. Ships	-	-	-	-	-	-
43. Automobiles	35 360	34 750	-	-	35 360	34 750
44. Aircraft	-	-	-	-	-	-
46. Other transport equipment	-	-	-	-	-	-
TOTAL (a)	1 482 395	1 729 807	740 033	803 873	2 222 428	2 533 680
b. Other than machinery and vehicles						
1. Agriculture, fishing and trapping	37 186	1 850	-	-	37 138	1 850
2. Mining	58 761	4 229	-	-	58 761	4 229

3. Food	-	-	-	-	-	-
4. Beverages	5 283	14 898	-	-	5 283	14 898
5. Tobacco	995	2 083	-	-	995	2 083
6. Textiles	14 898	5 283	-	-	14 898	5 283
7. Clothing	15 248	569	-	-	15 248	569
8. Leather	2 083	995	-	-	2 083	995
9. Footwear	110 051	6 761	214 194	2 247	324 245	9 008
10. Wood and wood products	225 911	73 053	187 357	56 046	413 268	129 099
11. Pulp, paper and paper products	73 053	225 911	207 576	192 022	280 629	417 933
12. Printing and publishing	-	-	-	-	-	-
13. Furniture	16 847	4 269	11 593	4 759	28 440	9 028
14. Industrial chemicals	-	-	-	-	-	-
15. Drugs	45 767	41 223	-	-	45 767	41 223
16. Other chemical products	-	-	-	-	-	-
19. Rubber products	623	4 738	-	-	623	4 738
20. Plastic products	35 103	48 063	-	-	35 103	48 063
21. Glass and glass products	2 880	903	-	-	2 880	903
23. Other non-metallic mineral products	-	-	9 953	76 092	9 953	76 092
24. Ferrous metals	31 673	47 616	-	-	31 673	47 616
25. Non-ferrous metals	-	-	112 318	4 494	112 318	4 494
26. Fabricated metal products	94 667	95 877	55 971	12 558	150 638	108 435
47. Sporting and athletic goods	2 999	2 327	-	-	2 999	2 327
48. Other manufacturing products	185 923	42 023	253 354	12 444	439 277	54 467
49. Energy and water supply	-	-	-	-	-	-
50. Construction	-	-	17 331	5 724	17 331	5 724
51. Trade, hotels and restaurants	-	-	718 723	134 701	718 723	134 701
53. Communication	-	-	94 577	8 454	94 577	8 454
54. Computer and data processing services	-	-	42 329	100 202	42 329	100 202
55. Services to business	-	-	206 727	1 258 262	206 727	1 258 262
56. Public administration, other personal services	-	-	254 412	544 389	254 412	544 389
TOTAL (b)	959 951	622 671	2 386 367	2 412 394	3 346 318	3 035 065
TOTAL (a+b)	2 442 346	2 352 478	3 126 400	3 216 267	5 568 746	5 568 745

Appendix table 3. Changes in labour productivity in manufacturing industries, average annual changes, %, 1980-85 and 1985-90

Industry	1980-85	1985-90
Food, beverages and tobacco	3.6	4.75
Textiles and clothing	4.32	3.52
Leather and footwear	4.51	5.01
Wood, except furniture	4.2	5.67
Furniture	3.21	4.41
Pulp and paper	6.05	3.35
Printing and publishing	3.49	4.28
Chemicals excl. drugs	3.3	5.96
Drugs	2.99	1.58
Petroleum and coal products	0.56	4.9
Rubber and plastic products	4.52	6.53
Non-metallic mineral products	2.48	5.74
Basic metals	4.95	6.13
Fabricated metal products	5.16	10.66
Metallurgical machines	14.03	6.03
Pulp and paper making machines	7.8	7.47
Computers	10.46	11.4
Other machinery	6.39	3.07
Electrical equipment for industry	5.53	11.96
Telecommunication equipment	10.31	15.48
Other electrical equipment	2.61	9.49
Ships	4.38	5.04
Railway transport equipment	3.19	20.35
Aircraft	5.9	1.36
Automobiles, other transport equipm.	2.38	4.75
Instruments	10.08	3.69
Other manufacturing	6.05	-0.64
Manufacturing total	**4.86**	**6.26**

Appendix table 4. Changes in total factor productivity in manufacturing indusries, average annual changes, %, 1980-85 and 1985-91

Industry		1980-85	1985-91
31	Food, beverages and tobacco	2	2.9
321	Textiles and clothing	2.8	-0.5
323	Leather and footwear	3.8	1.9
331	Wood, except furniture	2.6	1.4
332	Furniture, except primarily of metal	1.3	1.9
341	Paper and paper products	2.9	1.4
342	Printing and publishing	0.7	0.4
351	Chemicals	0.7	1
353	Petroleum refining	0.1	4.4
355	Rubber and plastic products	3.8	0
36	Non-metallic mineral products	0.9	1.2
37	Basic metals	5	3.3
381	Fabricated metal products incl. machinery	5.3	0.7
383	Electrical machinery. instruments	4.6	6.4
384	Transport equipment	2.7	1.2
39	Other manufacturing	4.5	2.4
3	**Total**	**3.3**	**2**

Source: Statistics Finland

Appendix table 5. Correlations of the variables in the earlier (upper table) and the latter period (below)

	dti81	tind81	hii81	fii81	hci81	fci81	spq85	tii81	tci81	hti81	fti81
dti81	1										
tind81	0.5029	1									
hii81	0.1068	0.5834	1								
fii81	0.6758	0.7747	0.2718	1							
hci81	-0.087	0.3295	0	-0.154	1						
fci81	-0.01	0.4703	0.0211	-0.038	0.7476	1					
spq85	0.9326	0.534	0.2912	0.6817	-0.174	-0.09	1				
tii81	0.5828	0.8656	0.6443	0.9111	-0.123	-0.021	0.6665	1			
tci81	-0.036	0.4514	0.0153	-0.079	0.8754	0.9755	-0.123	-0.056	1		
hti81	0.0635	0.6664	0.9173	0.188	0.3979	0.317	0.1979	0.5423	0.3625	1	
fti81	0.606	0.9184	0.2554	0.8858	0.208	0.43	0.5742	0.8133	0.3819	0.3171	1

	dti85	tind85	hii85	fii85	hci85	fci85	spq89	tii85	tci85	hti85	fti85
dti85	1										
tind85	0.515	1									
hii85	0.47	0.6763	1								
fii85	0.6576	0.8413	0.6318	1							
hci85	-0.044	0.4774	-0.101	0.0465	1						
fci85	-0.158	0.4265	-0.135	-0.054	0.8735	1					
spq89	-0.013	-0.214	-0.086	-0.031	-0.285	-0.327	1				
tii85	0.6493	0.8591	0.8314	0.956	-0.005	-0.09	-0.055	1			
tci85	-0.125	0.4552	-0.128	-0.023	0.9393	0.9875	-0.323	-0.065	1		
hti85	0.4198	0.8522	0.8895	0.6126	0.3649	0.2753	-0.211	0.7758	0.3119	1	
fti85	0.5066	0.9649	0.4954	0.8642	0.4816	0.4558	-0.192	0.807	0.4773	0.6848	1

Appendix table 6. Estimation results for models with average annual changes (%) in total factor productivity in 1980 to 1985 or 1985 to 1991 as the dependent variable and combined periods

Variable	Model T14	Model T15	Model T16	Model T17	Model T18	Model 19
Constant	3.1541	3.2047	3.1149	2.9535	4.1655	4.3120
	(4.47)	(4.15)	(4.10)	(3.30)	(2.66)	(4.18)
timed	-0.6585	-0.6343	-0.6772	-0.6185	-0.8614	-0.8107
	(-1.17)	(-1.07)	(-1.15)	(-0.99)	(-1.40)	(-1.38)
dti	0.2189	0.2147	0.2210	0.2241	0.3071	0.2093
	(3.79)	(3.38)	(3.67)	(3.29)	(1.76)	(3.29)
tind	-0.3861					
	(-1.79)					
spq	0.0182	0.0169	0.0184	0.0176	0.0384	0.0361
	(0.50)	(0.45)	(0.50)	(0.45)	(1.00)	(0.98)
tii		-0.3595				
		(-1.35)				
tci		-0.4410				
		(-1.16)				
hti			-0.2976			
			(-0.51)			
fti			-0.4296			
			(-1.24)			
hii				-0.1641	-1.9589	-1.8752
				(-0.26)	(-1.90)	(-1.94)
fii				-0.4716	-2.1587	-2.0525
				(-1.12)	(-2.50)	(-2.52)
hci				-1.8856	-2.5826	-2.5422
				(-0.90)	(-0.85)	(-1.30)
fci				0.1932	0.9894	0.9262
				(0.20)	(0.68)	(0.97)
hii*fii					1.2914	1.1586
					(2.19)	(2.21)
dti*fii					-0.0368	
					(-0.60)	
hci*fii					-0.0024	
					(-0.002)	
Adjusted R^2	0.3361	0.3114	0.3114	0.2732	0.327	0.3748
SEE	1.4092	1.4351	1.4352	1.4745	1.4188	1.3648
F statistics	4.9243	3.8044	3.804	2.6643	2.5065	3.3229
Number of observations	32	32	32	32	32	32

t statistics in brackets below the coefficients

E L I N K E I N O E L Ä M Ä N   T U T K I M U S L A I T O S (ETLA)
THE RESEARCH INSTITUTE OF THE FINNISH ECONOMY
LÖNNROTINKATU 4 B,   SF-00120 HELSINKI

Puh./Tel. (90) 609 900   Telefax (90) 601 753
Int. 358-0-609 900   Int. 358-0-601 753

KESKUSTELUAIHEITA - DISCUSSION PAPERS ISSN 0781-6847

No 476 PASI AHDE, ETLAn ennustejärjestelmän panos-tuotoskehikko. 31.01.1994. 60 s.

No 477 SYNNÖVE VUORI, Yritysten ja toimialojen väliset teknologiakytkennät Suomen teollisuudessa. 31.01.1994. 41 s.

No 478 OLLI TAHVONEN, CO_2 Taxation and Dynamics of Fossil Fuel Prices. 31.01.1994. 31 p.

No 479 TEPPO I. KYHERÖINEN, Teletoiminnan kansallinen kilpailukyky. 04.02.1994. 91 s.

No 480 KATI KORHONEN, Advantage Finland - Metals Production Technology. 15.02.1994. 34 p.

No 481 PASI KUOKKANEN, Energian tuotannon koneet ja laitteet. 15.02.1994. 46 s.

No 482 GEORG ANGENENDT, Identification and Discussion of Parameters that can be used to Analyze Industries with Michael E. Porter's System of Determinants that Influence the Competitive Position of Nations' Industries.

No 483 MIKA WIDGRÉN, Voting Rule Reforms in the EU Council: Needs, Means and Consequences. 10.03.1994. 40 p.

No 484 RITA ASPLUND, Teollisuuden työntekijöiden palkat ja inhimillinen pääoma. 06.04.1994. 75 s.

No 485 JARMO VEHMAS, Massa- ja paperiteollisuuden elinkaariarviointi ja metsäteollisuuden ympäristöhaasteet. 06.04.1994. 57 s.

No 486 JUHANA A.A. HEIKKILÄ, Corporate Venture Capital mallina suuryritysten ja pk-yritysten yhteistyölle. 07.04.1994. 63 s.

No 487 SUVI HINTSANEN, Energia-alan tietämyspohjainen vienti. 07.04.1994. 49 s.

No 488 JULIANNA BORSOS, Foreign Companies in Estonia - Industrial Environment and Experiences. 30.03.1994. 82 s.

No 489 ANTTI PUTUS, Matkapuhelinteollisuuden kotimainen kehitys ja kilpailukyky. 11.04.1994. 41 s.

No 490 JARI ILKKA, Kirjapainojen kansallinen kilpailukyky ja teollinen tulevaisuus. 14.04.1994. 54 s.

No 491 PASI KUOPPAMÄKI, European Markets for Corporate Control: A Study of Takeovers' Influence on Corporate Behavior and Implications on EC Competition Policy. 25.04.1994. 131 p.

No 492 TOMI TORRI, The World Economy of Metals; A Finnish Perspective. 02.05.1994. 49 p.

No 493 PIIA KAIPAINEN, Competitive Advantage of Finnish Steel Industry. 02.05.1994. 76 p.

No 494 ERKKA HOPPONEN, Itsenäisen voimantuotannon rahoitus ja kilpailukyky. 16.05.1994. 75 s.

No 495 JOUNI P. MÄKELÄ, Teleklusterin tutkimus- ja kehitystoiminta sekä koulutus ja konsultointi. 16.05.1994. 67 s.

No 496 JYRKI RUUTU, Tuntipalkkojen ja työmäärän jousto teollisuudessa laman aikana. 18.05.1994. 68 s.

No 497 MIKA MALIRANTA, Suomen työn tuottavuuden kansainvälinen taso ruoan, juomien ja tupakkatuotteiden valmistuksessa. Kahdenvälinen vertailu Ruotsiin ja Yhdysvaltoihin. 24.05.1994. 23 s.

No 498 MAARIT SÄYNEVIRTA - PEKKA YLÄ-ANTTILA, Teknologiaintensiivisten yritysten kansainvälistyminen. 06.06.1994. 54 s.

No 499 PETTERI KAUPPALA, Matkustajalaivaliikenteen kansallinen kilpailukyky. 06.06.1994. 65 s.

No 500 KAAREL KILVITS, Current State of Estonian Industry. The basic material prepared in autumn 1993 for the joint Estonian-Finnish study project on "the Future of Estonian industry". 10.06.1994. 74 p.

No 501 KALLE LAAKSONEN - RAIJA VOLK, Elintarvikeklusterin kilpailukyky - Väliraportti. 20.06.1994. 59 s.

No 502 SYNNÖVE VUORI, Teknologian tutkimuksen nykytila Suomessa. 21.06.1994. 23 s.

No 503 PETRI ROUVINEN, Hyvinvointiklusterin kilpailukyky - Väliraportti. 27.07.1994. 66 s.

No 504 SYNNÖVE VUORI, R&D, Technology Diffusion and Productivity in Finnish Manufacturing. 30.08.1994. 27 p.

Elinkeinoelämän Tutkimuslaitoksen julkaisemat "Keskusteluaiheet" ovat raportteja alustavista tutkimustuloksista ja väliraportteja tekeillä olevista tutkimuksista. Tässä sarjassa julkaistuja monisteita on mahdollista ostaa Taloustieto Oy:stä kopiointi- ja toimituskuluja vastaavaan hintaan.

Papers in this series are reports on preliminary research results and on studies in progress. They are sold by Taloustieto Oy for a nominal fee covering copying and postage costs.

d:\ratapalo\DP-julk.sam/30.08.1994