CHAPTER 9

INFORMATION TECHNOLOGY, WORKPLACE ORGANISATION, HUMAN CAPITAL AND FIRM PRODUCTIVITY: EVIDENCE FOR THE SWISS ECONOMY[1]

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Abstract

This chapter is based on a multivariate cross-section analysis of data of 1382 Swiss firms for the year 2000. It shows that labour productivity correlates positively **a)** ***with ICT indicators measuring the intensity of use of internet and intranet respectively by firms' employees;*** **b)** ***with variables for new forms of workplace organisation such as team-work, job rotation and decentralisation of decision making; and*** **c)** ***with human capital intensity. Some evidence is also found for complementarities between human capital and ICT capital with respect to productivity but not between organisational capital and the other two kinds of inputs.***

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9.1 Introduction

Over the past ten to fifteen years it has become clear that production of goods and services in developed economies increasingly requires not only such traditional factors as physical capital and labour, but also skills, know-how, organisational structures and other factors referred to as "intangible" assets. Investment in information and communication technologies (ICT) has become recognised as one of the most prominent of these factors and there has been extensive empirical research on this issue over the past years (see Pilat and Lee 2001 and OECD 2003 for recent reviews of the empirical literature). The contribution of human capital to economic growth at aggregate, sectoral and firm levels has been properly appreciated for a long time (see *e.g.* Jorgenson and Fraumeni, 1995). Recently, many prominent economists have been engaged in an intensive discussion on the reasons for the observed shift of labour demand towards high-skilled workers (see *e.g.* Johnson, 1997 and the other contributions of the symposium in the Spring 1997 issue of the *Journal of Economic Perspectives)*. New organisational practices are a further important intangible factor whose impact on firm efficiency and performance has been analysed over the past years (see Arnal *et al.*, 2001 and Murphy, 2002 for a survey of the empirical literature on this subject).

Already from the beginning of the nineties some authors pointed to the relevance of complementarities between the factors ICT, organisation and human capital as the most important characteristic of a new firm paradigm (see *e.g.* Milgrom and Roberts 1990). Since then a number of empirical studies have shown that such effects do exist and contribute significantly to firm performance (see Brynjolfsson and Hitt, 2000 for a review of the empirical literature in this field).

The present study explores empirically the hypothesis that ICT, new organisational practices and human capital are important determinants of firm efficiency and performance, and that the combined use of these three factors leads to a mutual strengthening of their impact on firm performance. The analytical framework is that of a production function at firm level. The study's contribution to the empirical literature consists in being the first empirical study of this type for Switzerland.[2] The study uses a rich data set at the firm level which was collected by means of a postal survey. It gives particular attention to the complementarities (using several approaches) and to the endogenisation of the technology and organisation variables. In addition, we focused on some statistical problems typically related to survey data; multiple imputations were used to substitute for missing values (to address the problem of item non-response) and some sensitivity analysis was done with respect to the applied imputation methods. Despite these advantages there are also shortcomings of the study, the principal one being that it is only a cross-section analysis which does not allow the test of causal relations, the use of lags between variables, etc.

The set-up of the chapter is as follows: section 9.2 sketches the analytical background of the chapter related to new theories on the combined influence of ICT, organisational factors and human capital on firm performance. Section 9.3 provides descriptive information on the existence and diffusion of ICT and new organisational practices in the Swiss business sector. In section 9.4 we describe our data. In section 9.5 we present and discuss the specification of the two versions of the empirical model (the basic model and the "compact" model). Sections 9.6 and 9.7 contain the results of the econometric estimates of the basic model and the "compact" model. In section 9.8 we present results on the complementarities. Finally, we summarise the main findings, indicate some directions for future research and draw some policy conclusions.

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2. Recently the determinants of the adoption of computer-based manufacturing technologies as well as the adoption of ICT in the Swiss business sector were investigated empirically (see Arvanitis and Hollenstein, 2001, Hollenstein, 2002 and Chapter 3).

9.2 Analytical framework

The new firm model

The past ten to fifteen years have witnessed a constellation of important changes in the production process, such as the extensive use of computer-aided production technologies, the advances in information and communication technologies, the emergence of new ideas on how to organise firms, changes in the skill requirements of labour and changes in employee preferences towards more flexible working conditions. On this basis, recently many authors have even postulated a shift to a new "firm paradigm". Some of them focus their attention mainly on technological changes, some find the introduction of new organisational practices a central characteristic of this "paradigm change". A third group concentrates primarily on the shift of firm demand to high-skilled labour in the past 20 years and analyses the determinants of this shift. In this section we briefly review some of this literature.

Milgrom and Roberts (1990) focus mainly on manufacturing and proclaim the replacement of the "mass production model by the vision of a flexible multi-product firm that emphasizes quality and speedy response to market conditions while utilizing technologically advanced equipment and new forms of organization" (p. 511). Changes in the production techniques and their implications for firm efficiency and performance are the main subjects of their theoretical analysis. Lindbeck and Snower (2000) analyse the shift from "'Tayloristic' organisation (characterised by specialisation by tasks) to 'holistic' organisation (featuring job rotation, integration of tasks and learning across tasks)" (p. 353). Bresnahan *et al.* (2002) take the relative demand of skilled-labour as the starting point of their analysis and consider the increased use of "complementary systems" of information technologies, workplace organisation and product innovation as drivers of skill-biased technical change. A point which is central in all types of analysis and a common characteristic of these studies is the existence of complementarities among several factors which mutually enhance their impact on firm performance.

Role of ICT

The benefits of ICT for a firm include savings of inputs, general cost reductions, higher flexibility, improvement in product quality, etc. The new technology may save labour or some specific labour skills; it may reduce capital needs through, for example, increased utilisation of equipment, reduction of inventories or space requirements, etc. It may also lead to higher product quality or better conditions for product development. Moreover, it may increase the flexibility of the production process allowing the exploitation of economies of scale (see *e.g.* Milgrom and Roberts, 1990, 1995). A specific feature of ICT is related to networking and communication. As new technologies reduce the cost of lateral communication, firms use these technologies to facilitate communication among employees and reduce co-ordination costs. Monitoring technologies can also be used to reduce the number of supervisors required in the production process. Thus, the use of ICT has direct implications for firm organisation.

While inventions that lead to improvements in ICT are readily available throughout the economy, complementary organisational changes involve a process of co-invention by individual firms (Bresnahan and Greenstein, 1997). Identifying and implementing such organisational changes is difficult and costly. These adjustment difficulties lead to variation across firms in the use of ICT, its organisational complements and the resulting outcomes.

Role of new organisational practices

Theories have also been developed to explain why these new high-skill, high-involvement workplaces may be more effective (see *e.g.* Ichniowski *et al.*, 2000). These can be divided, first, into theories that focus on the effort and motivation of workers and work groups; these suggest that due to the positive worker incentives created by new organisational forms performance increases. A second group of theories focuses on changes in the structure of organisations that improve efficiency. We concentrate here mainly on this second group. These theories imply that new arrangements can make organisational structures more efficient. For example, decentralising decision-making to self-directed teams can reduce the number of supervisors and middle managers required while improving communication; employee involvement can eliminate or reduce grievances and other sources of conflict within the firm, thus improving performance.

For these organisational practices as for other factors and inputs, interdependencies exist. Some of the changes in work design are associated with the introduction and diffusion of information technologies within the firm. For example, Greenan and Guellec (1994) show in a theoretical paper that the relative efficiency of a centralised mode of firm organisation in which knowledge is confined to specialised workers and a decentralised one in which every worker participates in learning depends on the technological level of the firm: "whereas the centralized style is more efficient when the technological level is low, the decentralized one becomes more efficient when the technological level is higher" (p. 173).

Role of human capital

The shift towards skilled workers appears to have accelerated in the past twenty years. While many factors have contributed to this increase most authors think that this effect is attributable primarily to skill-based technical change. The size, breadth and timing of the recent shift in labour demand have led many to relate skill-biased technical change to the largest and most widespread new technology of the past years, ICT (see Bresnahan *et al.*, 2002). On the one hand, high-skilled labour is a precondition for the use of ICT; for example, training in problem-solving, statistical process controls and computer skills can increase the benefits of ICT. On the other hand, highly computerised systems not only systematically substitute computerised decision-making for human decision-making in routine work, but also produce a large quantity of data which requires high-skilled workers, managers and professionals to get adequately utilised.

Role of complementarities

The use of ICT, new organisational practices and human capital build a "complementary system" of activities (Bresnahan *et al.* 2002, p. 341ff; Milgrom and Roberts 1995, p. 191ff.). According to Milgrom and Roberts (1990, p. 514), "the term 'complement' is used not only in the traditional sense of a specific relation between pairs of inputs but also in a broader sense as a relation among groups of activities". For example, modern advanced manufacturing techniques consist of a bundle of technology elements implying considerable complementarities among these elements; a standard illustration refers to the use of CAD which leads to complementarities with other programmable manufacturing equipment. But complementarities are also found with respect to organisation and human capital.

According to the formal definition of complementarities of a firm's two discrete activities with respect to some performance variable, the following proposition can be postulated based on the theory of super modularity (see *e.g.* Athey and Stern, 1998, p. 8f.). Suppose there are two activities A_1 and A_2, each activity can be performed by the firm ($A_i = 1$) or not ($A_i = 0$). The function $F(A_1, A_2)$ (*e.g.* F is firm performance) is "super modular" and A1 and A2 are "complements" only if: $F(1,1) - F(0,1) >= F(1,0) - F(0,0)$, *i.e.* performing the first activity together with the second one yields a higher incremental effect on F (performance) than when performing the first activity alone. This proposition is quite useful for testing complementarities empirically.

Production function framework

The discussion above shows that there are some common testable hypotheses with respect to the contribution of ICT, new organisational practices and human capital to firm efficiency and performance which can best be put together in the framework of a production function. Besides the classical production factors labour and physical capital this also contains the new ones, ICT capital, organisation capital and human capital (see Brynjolfsson and Hitt, 2000, for a recent survey of the empirical literature on this topic):

- Hypothesis 1: there are considerable direct positive effects of ICT, organisation and human capital on firm performance.

- Hypothesis 2: there are considerable indirect positive effects of these factors on firm performance which can be traced back to complementarities among them.

9.3 Use of ICT and new organisational practices in the Swiss business sector

Information and communication technologies (ICT)

Between 1995 and 2000, as in many other OECD countries, the use of information technologies in the Swiss business sector increased at a tremendous rate. In 2000, 94.0% of all firms (with more than five employees) used a personal computer, 86.1% used e-mail and 78.0% used Internet; about 55% of Internet users disposed of a homepage (see Arvanitis *et al*,. 2002). Many firms used also more complicated networking-technologies (electronic data exchange with other firms (EDI), firm computer networks (LAN/WAN), Intranet and Extranet).

We concentrate here on Internet and Intranet, both of them technologies which permit a high degree of networking among various activities of firms. 81.3% of manufacturing firms used Internet in the year 2000, about the same as firms in the service sector (79.5%) but significantly more often than construction enterprises (69.4%) (see Table 9.1). On the whole 27.0% of firms used an internal network (Intranet) in 2000; this percentage was about the same in the manufacturing and in the service sector (28.2% and 31.6% respectively), it was considerably lower in the construction industry (11.3%).

On the whole, Swiss firms are well-equipped with information technology; compared to other countries Switzerland is ranked behind the USA and the Scandinavian countries (with respect to the overall diffusion of information technologies), but ahead of other European countries (see Arvanitis and Hollenstein, 2002).

More important with respect to firm performance than the incidence of ICT may be the intensity of the use of new technology within a firm. Table 9.2 presents some information on the percentage of employees using Internet and Intranet respectively. On average, 28.6% of the employees of all firms applying this technology used Internet in 2000 in their work, 50.7% of the employees of all firms having Intranet made use of it in their daily work. There are considerable differences with respect to the intensity of use of ICT among sectors of the economy. The employees of service firms are more strongly integrated via Internet and/or Intranet (36.5% and 59.4% respectively) than those in manufacturing (20.0% and 41.7% respectively) and in construction firms (15.7% and 34.9% respectively).

Table 9.1. **Diffusion of ICT and new organisational practices in the Swiss business sector**
(percentage of firms)

	Manufacturing	Construction	Services	Total
Internet				
Before 1995	1.6	0.0	2.2	1.7
1995-1997	14.0	13.7	14.7	14.4
1998-2000	65.7	55.7	62.6	62.0
Total	81.3	69.4	79.5	78.1
Intranet				
Before 1995	1.6	0.5	2.4	1.8
1995-1997	6.1	1.9	7.6	6.2
1998-2000	20.5	8.9	21.6	19.0
Total	28.2	11.3	31.6	27.0
Job rotation				
Before 1995	7.8	4.7	4.1	5.1
1995-1997	2.3	0.5	1.9	1.8
1998-2000	7.1	0.1	2.9	3.5
Total	17.2	5.3	8.9	10.4
Team-work				
Before 1995	18.6	14.2	17.0	16.9
1995-1997	11.3	3.5	7.0	7.4
1998-2000	14.5	13.4	9.4	11.4
Total	44.4	31.1	33.4	35.7

Note: Data of 2 648 firms (Internet, Intranet) and 1 667 firms (job rotation, team work) resp.; multiple imputations for missing values (see section 9.4); the data were corrected for unit non-response bias and weighted in order to reflect the population of Swiss enterprises belonging to the two-digit industries listed in Table A9.1.

New organisational practices

Two main forms of flexible organisation are team-working (work in formally organised project groups, teams, quality circles, semi-autonomous groups, etc.) and job rotation. According to Table 9.1, 35.7% of Swiss firms (with at least five employees) had introduced team-working, 10.4% of them job rotation. There is a considerable acceleration of the adoption of such organisational practices in the Swiss economy since 1995. 16.9% of all firms had already introduced team-working before 1995, 7.4% did it between 1995 and 1998, 11.4% between 1998 and 2000. For job rotation the corresponding shares of firms are considerable lower, but also increasing; only 5.1% of firms used job rotation before 1995, 1.8% of them introduced this organisational practice between 1995 and 1997, 3.5% between 1998 and 2000. These forms of flexible workplace organisation could be found in all sectors of the economy, but the most in manufacturing, particularly job rotation. 20.8% of all firms reported that they intensively used team-work; for job rotation 4.2% of firms reported that they intensively use it (see Table 9.2). There are no significant differences with respect to the intensity of use of these forms of flexible organisation among sectors of the economy.

Table 9.2. **Intensity of use of ICT and new organisational practices, 2000**

	Manufacturing	Construction	Services	Total
	Average percentage of employees using a technology			
Internet	20.0	15.7	36.5	28.6
Intranet	41.7	34.9	59.4	50.7
	Percentage of firms using an organisational practice intensively[1]			
Job rotation	5.0	3.9	3.3	4.2
Team work	20.7	16.0	22.4	20.8

1. Percentage of the firms reporting value 4 or value 5 on a five-point Likert scale.

Note: Data of 2 648 firms (Internet, Intranet) and 1 667 firms (job rotation, team-work) resp.; multiple imputations for missing values (see section 9.4); the data were corrected for unit non-response bias and weighted in order to reflect the population of Swiss enterprises belonging to the two-digit industries listed in Table A9.1.

Parallel to these organisational changes a decentralisation of decision-making within enterprises has also taken place. 40% of all firms declared in a representative survey conducted in 2000 that management has delegated various competencies to their employees or teams of employees since 1995, aiming at a decentralisation of firms‘ decision-making process (see Table 9.3). Only 2.9% of these found that a shift towards stronger competencies of managers and not of workers had taken place since 1995; for 57.0% of firms there was no change with respect to within-firm competency delegation. This decentralisation effect was strongest in manufacturing. The shift of competencies towards workers was only weakly reflected in changes of the formal organisational structure: only 9.4% of all firms reported a decrease in the number of managerial levels since 1995, for 85.8% the overall organisational structure remained unchanged (Table 9.3). There were no significant differences among the sectors of the economy with respect to this phenomenon.

Vocational education and job-related training

The share of employees with university and other tertiary-level education (business and technical colleges, etc.) in the Swiss business sector was 18.7% in 1999 (Table 9.4). 47.5% of employees had a full vocational education ending with a formal degree, 27.8% had only some vocational education without a formal degree, or no vocational education at all. The share of employees with full vocational education did not vary much among the sectors of the economy; the significant differences with respect to overall formal education in Table 9.4 come from the shares of employees with tertiary and low education respectively. Manufacturing firms had on average a considerably higher share of employees with tertiary education (22.2%) than firms belonging to the service (16.8%) or the construction sector (13.4%). In accordance, only 21.9% of employees of manufacturing firms had low education, whereas this share is 32.8% in the service and 29.2% in the construction sector.

Table 9.4 also contains some information on job-related training: 29.0% of all employees on the average attended training courses in 1999; in the service sector this percentage was higher (34.3%), in manufacturing it was lower than the average (22.2%).

Table 9.3. **Changes with respect to some organisational practices since 1995 (percentage of firms)**

Change in the number of managerial levels				
	Decrease (1)	No change (2)	Increase (3)	Difference (1)-(3)
Manufacturing	13.6	80.7	5.7	7.9
Construction	13.6	82.8	3.6	10.0
Services	6.3	88.9	4.8	1.6
Total	9.4	85.8	4.8	4.6
Shift of competences				
	No shift (1)	Toward employees (2)	Toward managers (3)	Difference (2)-(3)
Manufacturing	50.0	48.0	2.0	46.0
Construction	78.2	21.2	0.6	20.6
Services	53.6	42.4	4.0	38.4
Total	57.0	40.0	2.9	37.1

Note: Data of 1 667 firms; multiple imputations for missing values (see section 9.4); the data were corrected for unit non-response bias and weighted in order to reflect the population of Swiss enterprises belonging to the two-digit industries listed in Table A9.1.

Table 9.4. **Formal education and job-related training of employees in the business sector, 1999**

	Manufacturing	Construction	Services	Total
Formal education (average share of employees)				
University	7.4	1.7	3.6	5.0
Other tertiary-level education	14.8	11.7	13.2	13.7
Vocational education; formal degree	49.1	49.0	45.6	47.4
Vocational education without formal degree; no vocational education	21.9	29.2	32.8	27.8
Job-related training (average share of employees attending training courses)				
	22.3	21.4	34.3	29.0

Note: Data of 2 648 firms; multiple imputations for missing values (see section 9.4); the data were corrected for unit non-response bias and weighted in order to reflect the population of Swiss enterprises belonging to the two-digit industries listed in Table A9.1.

Impact of ICT and new organisational practices on firm performance

It is interesting to compare managers' subjective assessment of the impact on performance of the introduction and use of ICT and new organisational practices with the results of a micro econometric model like the one to be presented in one of the next sections. 60.8% of all firms using ICT reported a positive impact of ICT use on overall firm efficiency, 38.1% of them could not ascertain any change, only 1.1% found that the use of ICT led to an efficiency decrease (see Table 9.5). There are no large differences among the sectors (with the exception of the construction sector). Even if we take into consideration that managers may have a "positive bias" toward ICT use, it is quite remarkable that almost 40% of users could not identify any positive impact on efficiency; firms also do not consider ICT to be a panacea for all kinds of problems. Our analysis also finds an overall positive effect of ICT use.

In the face of our results (see section 9.7) it is rather astonishing that 70.4% of all firms applying some or all of the new organisational practices assessed the impact of these changes on firm efficiency to be positive; only 26.7% of them could not find any influence. The assessments with respect to the impact of organisational change on firm efficiency are quite similar among the sectors of the economy. Do managers exaggerate this effect in order to justify their own involvement in introducing and carrying through new organisational practices? The question is sensible but difficult to answer without further information.

Table 9.5. **Impact of ICT and new organisational practices on overall firm efficiency (percentage of firms)**

	Decrease (1)	No change (2)	Increase (3)	Difference (3)-(1)
ICT				
Manufacturing	0.8	40.9	58.3	57.5
Construction	0.4	50.0	49.6	49.2
Services	1.3	35.6	63.1	61.8
Total	1.1	38.1	60.8	59.7
New organisational practices				
Manufacturing	3.3	26.9	69.8	66.7
Construction	7.7	29.8	62.5	54.8
Services	2.1	26.5	71.4	69.3
Total	2.8	26.7	70.4	67.6

Note: Data of 2 648 firms (Internet, Intranet) and 1 667 firms (new organisational practices) resp.; multiple imputations for missing values (see section 9.4); the data were corrected for unit non-response bias and weighted in order to reflect the population of Swiss enterprises belonging to the two-digit industries listed in Table A9.1.

9.4 Data

The data used in this study were collected in the course of a specific survey among Swiss enterprises using a questionnaire which included questions on the incidence and within-firm diffusion of several ICT technologies (e-mail, Internet, Intranet, Extranet, etc.) and new organisational practices (team-work, job rotation, employees' involvement, etc.) on employees' vocational education and job-related training, flexibility of working conditions, and labour compensation schemes.[3] The survey was based on a (with respect to firm size) disproportionately stratified random sample of firms with at least 20 employees covering all relevant industries of the business sector as well as firm size classes. The survey on the whole covered 28 industries and, within each industry three industry-specific firm size classes with full coverage of the upper class of large firms. Answers were received from 1667 firms,

3. The questionnaire was based to a considerable extent to similar questionnaires used in earlier surveys (see EPOC 1997, Francois *et al.* 1999, Vickery/Wurzburg 1998, Statistics Canada 1999). Versions of the questionnaire in German, French and Italian can be found at www.kof.ethz.ch.

i.e. 39.4% of the firms in the underlying sample.[4] The response rates do not vary much across industries and size classes with a few exceptions (over-representation of paper and energy industry, under-representation of hotels, catering and retail trade; see Table A9.1 in the annex of this chapter for the structure of the used data set by industry and firm size class). The non-response analysis (based on a follow-up survey of a sample of the non-respondents) did not indicate any serious selectivity bias with respect to the use of ICT and new organisational practices (team-work, job rotation). A careful examination of the data of these 1 667 firms led to the exclusion of 285 cases with contradictory or non-plausible answers; there remained 1 382 valid answers which were used for this analysis.

Further we used the multiple imputations technique by Rubin (1987) to substitute for missing values in the variables due to item non-response (see Donzé, 2001 for a detailed report on these imputations). In the estimations we inserted the mean of five imputed values for every missing value of a certain variable. To test the robustness of this procedure we estimated the basic model for the original data without imputed values (containing only 598 observations), for every single set of imputed values as well as for the mean of them; finally we calculated the mean and the variance of the parameters of the estimates based on the single five imputed values according to the method described in Donzé (2001) and compared the results. They showed a relatively high robustness of the estimated parameters; *e.g.* the estimates based on the mean of the imputed values and the estimates based on the average of the parameters estimated for the single sets of imputed values were quite similar. The largest divergence was related to the estimates based on the original data without imputed values.

9.5 Model specification and variable construction

Basic model

Throughout this study we use the logarithm of sales per employee as the dependent variable. As a consequence, we insert a right-hand variable to control for material and service inputs (logarithm of the value of material and service inputs per employee). Since we do not dispose of data on physical capital, we rely on extensive industry controls to seize the influence of this important variable.

As measures for technology input, particularly ICT input ("ICT capital"), we use the intensity of use of two important network technologies, Internet (linking to the outside world) and Intranet (linking within the firm). This intensity is measured by the share of employees using Internet and Intranet respectively in their daily work. The firms were asked to report this share not by a precise figure but within a range of twenty percentage points (1% to 20%, 21% to 40% and so on). Based on these data we constructed five dummy variables for each technology covering the whole range from 1% to 100% (see note to Table 9.6). The idea behind this variable is that a measure of the diffusion of a certain technology within a firm would be a more precise proxy for "ICT capital" than the mere incidence of this technology or some kind of simple hardware measure (*e.g.* number of PCs, etc.). We expect in general a positive correlation of technology variables with average labour productivity, in particular an increasing positive correlation with a higher percentage of employees using a certain technology.

4. The descriptive analysis of the data for ICT and human capital in section 3 was based on a sample of 2 648 firms with at least five employees. The information on organisation was raised only for firms with at least 20 employees (sample of 1 667 firms). As a consequence, we could use data for 1 667 firms for the econometric analysis.

Table 9.6. **Basic model: average labour productivity (log(sales per employee) 1999[1]) – OLS estimates**

Explanatory variables	All firms		Manufacturing	Services
	Original coeff.	Standardised coeff.		
Intercept	5.255***		5.332***	5.411***
	(0.142)		(0.170)	(0.256)
Log(materials/employee)[1]	0.741***	0.276	0.615***	0.094**
	(0.243)		(0.263)	(0.043)
Technology				
Use of Internet (% of employees)[2]				
1-20	0.038	0.027	0.033	0.034
	(0.043)		(0.044)	(0.095)
21-40	0.105**	0.061	0.149***	0.007
	(0.052)		(0.053)	(0.115)
41-60	0.141**	0.058	0.114	0.129
	(0.068)		(0.074)	(0.132)
61-80	0.297***	0.098	0.183*	0.379***
	(0.081)		(0.095)	(0.042)
81-100	0.214*	0.055	0.313	0.133
	(0.114)		(0.220)	(0.156)
Use of Intranet (% of employees)[2]				
1-20	0.126***	0.067	0.157***	0.058
	(0.043)		(0.050)	(0.074)
21-40	0.204***	0.120	0.167***	0.312***
	(0.048)		(0.049)	(0.110)
41-60	0.208***	0.131	0.198***	0.209**
	(0.052)		(0.049)	(0.095)
61-80	0.179***	0.088	0.167***	0.210**
	(0.052)		(0.059)	(0.092)
81-100	0.360***	0.167	0.228***	0.457***
	(0.074)		(0.082)	(0.121)
Workplace organisation				
Team-work[3]	0.072**	0.042	0.051	0.126*
	(0.036)		(0.039)	(0.073)
Job rotation[3]	-0.070	-0.020	-0.128*	0.098
	(0.076)		(0.077)	(0.210)
Delegation of competences from managers to employees:				
Overall delegation of competences from managers to employees[4]	-0.008	-0.006	-0.052*	0.078
	(0.027)		(0.028)	(0.054)
Employees competence to solve production problems[5]	0.105	0.032	0.160*	0.058
	(0.085)		(0.097)	(0.141)
Employees competence to contact customers[5]	0.114***	0.065	0.079*	0.148**
	(0.037)		(0.042)	(0.063)
Decrease of number of managerial levels[6]	0.013	0.004	-0.068	0.078
	(0.065)		(0.064)	(0.054)
Human capital				
Share of employees with high education[7]	0.275***	0.070	0.400***	0.232
	(0.114)		(0.138)	(0.184)
Share of employees receiving job-related training[8]	0.126**	0.048	0.177**	0.047
	(0.063)		(0.071)	(0.089)
Computer training[9]	0.060**	0.043	0.073**	0.030
	(0.028)		(0.030)	(0.059)

(continued on next page)

Table 9.6. **Basic model: average labour productivity (log(sales per employee) 1999[1]) – OLS estimates** *(continued)*

Working conditions, compensation				
Team compensation[10]	0.067**	0.045	0.054*	0.119**
	(0.029)		(0.030)	(0.059)
Part-time work[11]	-0.068**	-0.043	-0.061*	-0.100*
	(0.032)		(0.035)	(0.056)
Flexible working time[11]	-0.050*	-0.036	-0.053*	-0.065
	(0.026)		(0.028)	(0.058)
N	1 382		893	489
DF	50		41	31
SER	0.494		0.424	0.598
F	27.4***		15.2***	18.8***
R^2adj.	0.488		0.392	0.535

1. Number of employees calculated in full-time equivalents.
2. Dummy variables (value 1 for firms reporting that the share of employees using *Internet (Intranet*) is between 1% and 20%, 21% and 40%, 41% and 60%, 61% and 80%, 81% and 100% respectively; reference group: firms which do *not* use Internet (Intranet)).
3. Dummy variable (value 1 for firms reporting that the use of *team-work* (project groups, quality circles, semi-autonomous teams, etc.) or *job rotation* is "widespread" (values 4 and 5 on a five-point Likert scale)).
4. Dummy variable (value 1 for firms reporting that since 1995 (not further specified) competences were transferred from managers to employees).
5. Dummy variables (value 1 for firms reporting that at the workplace level employees have the competence to solve autonomously emerging *production problems* or to contact autonomously *customers* (values 4 and 5 on a five-point Likert scale)).
6. Dummy variable (value 1 for firms reporting that the number of *managerial levels* decreased since 1995).
7. Education at the *tertiary* level (universities, technical and business colleges, etc.).
8. Job-related training: internal and/or external training courses initialised or supported by the firm.
9. Dummy variable (value 1 for firms reporting that *computer training* is "important" (values 4 and 5 on a five-point Likert scale)).
10. Dummy variable (value 1 for firms reporting that employee compensation according to *team performance* is "important" (values 4 and 5 on a five-point Likert scale)).
11. Dummy variable (value 1 for firms reporting that *part-time work (flexible annual working time)* is "important" (values 4 and 5 on a five-point Likert scale)); estimations include also two-digit industry controls (27 dummies); ***, **, * denote statistical significance at the 1%, 5% and 10% level respectively; heteroscedasticity robust standard errors (White procedure).

The measurement of organisational inputs, here restricted to inputs related to workplace organisation, is an issue still open to discussion, since there is not yet any agreement among applied economists about the exact definition of "organisational capital" (see Black and Lynch, 2002, and Lev, 2003 for a discussion of this matter; see also Appelbaum *et al*,. 2000, Chapter 7 for definitions of high-performance work system variables). In order to choose the variables related to changes and/or introduction and use of new organisational practices at the workplace level we draw on the definition offered by Black and Lynch (2002). They distinguish two components of organisational capital (in a narrow sense, *i.e.* without training which we view as part of the human capital of the firm): "work design" and "employee voice". Examples of practices that are included in the first component are reengineering efforts that may involve changing the occupational structure of the workplace, the number of levels of management within the firm, the existence and diffusion of job rotation, and job share arrangements. The second component of organisational capital, "employee voice", is associated with practices such as individual job enrichment schemes, employees being consulted in groups, employees having more decision competences, the existence and diffusion of work in (formally constituted) teams, etc. Our data enable us to construct the following dummy variables covering most of the above-discussed aspects of organisational capital: intensive use of team-work (project groups, quality circles, semi-autonomous teams, etc.); intensive use of job rotation; decrease of the number of management levels; overall shift of decision competencies from managers to employees; employees having the competence to solve relatively autonomously emerging production problems (production) or to contact customers (sales) (see also note to Table 9.6). We expect an overall positive correlation of organisational variables with average labour productivity, but we do not have expectations about the sign for every single variable.

We include three more variables which are related to workplace organisation but are not components of organisational capital per se. The first one is referring to incentive-based compensation and is a dummy variable for the existence of employee compensation according to team-performance (see note to Table 9.6). The other two variables measure labour flexibility (dummy variable for the intensive use of part-time work) and working time flexibility (dummy variable for flexible yearly working time) (see also note to Table 9.6). With respect to the compensation variable the sign of the correlation with the dependent variable is not a priori clear; whether team-performance enhances employee incentives for higher performance is an open empirical question. Also the relation of part-time work to productivity is not clear in the empirical literature and depends on the overall conditions of the labour market as well as its institutional framework; we expect a positive effect for flexible annual working time as this does not only expand employee's sovereignty over time but also contributes to a more efficient combination of labour and machines.

A third important category of production inputs is related to human capital. We use three variables to approximate human capital: the share of employees with vocational education at the tertiary level (universities, business and technical colleges, etc.); the share of employees receiving job-related training (internal and/or external training courses initialised or supported by the firm); a dummy variable for strong orientation of training particularly to computer training (see also note to Table 9.6). According to standard analysis (see *e.g.* Barro and Lee, 1994) we expect a strong positive correlation of these variables to labour productivity.

"Compact" model

In the basic model ten dummy variables for the use of Internet and Intranet are proxies for "ICT capital", six organisational variables are used to approximate "organisational capital" and three variables are proxies for human capital. In order to be able to assess the relative significance of the three variable blocks for labour productivity, one has to make the overall measures for these variables comparable. We applied two separate procedures to construct composite indices for technology, organisation and human capital based on the proxies for these variables. In the first version a composite index was calculated as the sum of the standardised (average 0; standard deviation 1) values of the variables. For the technology variable (TECHNS) the original variables for the use of Internet and Intranet (measured on a five-point Likert scale) were used for the standardisation procedure (see also note to Table 9.7). The organisational variable (ORGANS) was constructed as a sum of the standardised values of the six constituent variables, the human capital variable (HUMANS) as a sum of the three constituent variables (see note to Table 9.7). In the second procedure we used the factor scores of the one-factor solution of a principal component factor analysis of the three sets of variables as composite indices for technology (TECHF), organisation (ORGANF) and human capital (HUMANF).

The "compact" model contained either the variables TECHNS, ORGANS and HUMANS or TECHF, ORGANF and HUMANF besides the variables for labour compensation, labour flexibility and working time flexibility and the controls for industry and material and service inputs. A second reason for specifying the "compact" model was the possibility of investigating the complementarities between technology, organisation and human capital; the composite indices are considered as metric variables and interaction terms of these variables can be inserted in the model (see section 9.8).

Table 9.7. **Compact model: average labour productivity (log(sales) per employee) 1999[1]) – OLS estimates of versions of the model with composite indices for technology, organisation and human capital based on standardised values (first version) or factor scores (second version)**

Explanatory variables	(1)	(2)	(3)	(4)	(5)	(6)
	Standardised variables			Factor scores		
Intercept	5.592***	5.588***	5.586***	5.640***	5.633***	5.615***
	(0.149)	(0.149)	(0.149)	(0.149)	(0.147)	(0.152)
Log(mat/employee)[1]	0.763***	0.762***	0.763***	0.763***	0.768***	0.759***
	(0.248)	(0.248)	(0.248)	(0.246)	(0.246)	(0.249)
TECHNS[2]	0.646***	0.676**	0.673***			
	(0.096)	(0.097)	(0.096)			
ORGANS[3]	0.190***	0.203***	0.184***			
	(0.062)	(0.067)	(0.063)			
HUMANS[4]	0.490***	0.399***	0.398***			
	(0.099)	(0.103)	(0.104)			
TECHNF[5]				0.148***	0.147***	0.168***
				(0.022)	(0.022)	(0.022)
ORGANF[6]				0.053***	0.055***	0.061***
				(0.015)	(0.015)	(0.015)
HUMANF[7]				0.079***	0.074***	
				(0.020)	(0.019)	
Team Compensation[8]	0.696**	0.677**	0.677**	0.621**	0.611**	0.729***
	(0.292)	(0.292)	(0.293)	(0.291)	(0.291)	(0.295)
Part-time work[9]	-0.716**	-0.708**	-0.712**	-0.701**	-0.695**	-0.700**
	(0.323)	(0.323)	(0.323)	(0.323)	(0.323)	(0.326)
Flexible working time[10]	-0.490*	-0.479*	-0.478*	-0.565**	-0.555**	-0.429
	(0.267)	(0.266)	(0.267)	(0.266)	(0.266)	(0.268)
Interaction terms:						
TECHNS*ORGANS		-0.022				
		(0.042)				
TECHNS*HUMANS		0.109**	0.096**			
		(0.053)	(0.048)			
ORGANS*HUMANS		-0.021				
		(0.042)				
TECHNF*ORGANF					-0.012	
					(0.019)	
TECHNF*HUMANF					0.009	0.028*
					(0.019)	(0.017)
TECHNF*ORGANF					0.012	
					(0.025)	

(continued on next page)

Table 9.7. **Compact model: average labour productivity (log(sales) per employee) 1999[1]) – OLS estimates of versions of the model with composite indices for technology, organisation and human capital based on standardised values (first version) or factor scores (second version)** *(continued)*

N	1 382	1 382	1 382	1 382	1 382	1 382
DF	34	37	35	34	37	34
SER	0.499	0.498	0.498	0.497	0.495	0.498
F	38.2***	35.4***	37.4***	39.0***	36.3***	38.6***
R^2adj.	0.478	0.479	0.479	0.487	0.486	0.480

1. Number of employees calculated in full-time equivalents.
2. Sum of the standardised variables for user intensity of Internet and Intranet (two variables measured on a five-point Likert scale).
3. Sum of the standardised variables for work place organisation (six dummy variables for: job rotation; team work; decrease of the number of managerial levels since 1995; overall transfer of (unspecified) competences from managers to employees since 1995; employees have at the workplace level the competence to solve autonomously emerging *production problems*; employees have at the workplace level the competence to contact autonomously *customers*).
4. Sum of the standardised variables for human capital (three variables: share of employees with high education; share of employees receiving job-related training; dummy variable for computer training).
5. Factor scores of a one-factor solution of principal component factor analysis of the two variables for information technology mentioned in note (2) above.
6. Factor scores of a one-factor solution of principal component factor analysis of the six variables for workplace organisation mentioned in note (3) above.
7. Factor scores of a one-factor solution of principal component factor analysis of the three variables for human capital mentioned in note (4) above.
8. Dummy variable (value 1 for firms reporting that employee compensation according to *team performance* is "important" (values 4 and 5 on a five-point Likert scale)).
9. Dummy variable (value 1 for firms reporting that *part-time work* is "important" (values 4 and 5 on a five-point Likert scale)); dummy variable (value 1 for firms reporting that *flexible annual working time* is "important" (values 4 and 5 on a five-point Likert scale)); estimations include also two-digit industry controls (27 dummies); ***, **, * denote statistical significance at the 1%, 5% and 10% level respectively; heteroscedasticity robust standard errors (White procedure).

9.6 Results for the basic model

Tables 9.6 contains the results of the OLS estimates of the basic model for all firms (column 1) as well as separately for the firms of the manufacturing and construction sector (column 3) and the service sector (column 4). Since the results are only cross-section estimates, it is not possible to state causal relations between the independent variables and the dependent variable. Nevertheless, some robust regularities come out, which if interpreted in the light of our hypothesis 1 (see section 2) could possibly indicate the direction of causal links. The overall fit of the model (R^2=0.488; column 1) is satisfactory for a cross-section investigation.

The coefficients of nine of the ten dummy variables for the intensity of use of Internet and Intranet, as expected, are positive and statistically significant. Only the coefficient for the lowest intensity category of Internet (1%-20% of employees using Internet in their daily work) is not significant. The general tendency is that the higher the intensity of use of these technologies among a firm's employees, the higher is also the positive correlation to labour productivity. The coefficients of the Internet dummy variables become larger the higher the share of the employees using this technology up to 80%; the coefficient of the fifth dummy variable (81%-100%) is somewhat lower than that of the fourth one (61%-80%). In the case of the Intranet dummies this regularity of increasing coefficients can be found up to 60%, then the next coefficient (61%-80%) is lower than that for the range of 41% to 60%, the coefficient for the range 81%-100% is the largest of the coefficients for

Intranet use. Thus, there is a more or less systematic positive correlation between the level of intensity of use of ICT and the level of labour productivity. With respect to Intranet there are no differences between manufacturing and service firms. According to the results in column 3 and 4 the use of Internet is less important for firm performance in the manufacturing than in the service sector, presumably due to the existence of a considerable share of production workers that do not perform a desk job and are not equipped with a PC and an Internet connection.

In the estimates for all firms we could find statistically significant positive effects for two organisational variables, for the within-firm widespread use of team-work (project groups, quality circles, semi-autonomous teams, etc.), a component of "work design", and for the existence of employee competence to contact autonomously firm customers (an aspect of "employee voice"). The team-work effect is considerably more important for the service than for the manufacturing firms; team-work is less relevant in manufacturing because of the lack of mass-production industries (*e.g.* automobile industry) in the Swiss economy which most often apply this organisational practice form (*e.g.* semi-autonomous production teams). No effect could be found for another dimension of "work design", the change of the number of management levels. The descriptive analysis showed that only few firms reported such a change (see Table 9.3), although the dominant discourse in the management literature in the nineties has been that the flattening of the overall firm structure would enhance firm performance. A possible explanation for this behaviour may be found in the size distribution of Swiss firms with a (relative to other economies) very large share of small firms with very few hierarchical layers. There was also no indication of significant effects for the overall delegation of competences from managers to employees (except for a slight negative effect for manufacturing). Finally, we obtained a statistically significant positive coefficient for employee competence to solve autonomously problems in the production sphere, but only for manufacturing in which physical production is dominant. We conclude that an overall shift of competences towards employees may prove to be too unspecific to lead to a positive performance impact; moreover it is the clear-targeted delegation of specific competencies from managers to employees, for example, with respect to production and customer problems that could enhance productivity.

On the whole, the organisational variables correlate considerably weaker with the dependent variable (and explain less of its variance) than the technological variables; the average absolute value of the standardised coefficients of the organisational variables is 0.028, that of the technological variables 0.087 (see column 2 in Table 9.6).

All three proxy variables for human capital, as expected, have statistically significant positive coefficients in the estimates for all firms. The strongest effect comes from formal education, but job-related training is also important; computer training seems to be the most effective type of training, it also helps to utilise ICT more efficiently (complementarity effect; see section 9.8). Human capital is more relevant for firm performance in the manufacturing than in the service sector on the whole. However, there are of course modern service industries in which the human capital intensity is very high (business services, banking and insurance). The average value of the standardised coefficients of the human capital variables is 0.054; thus, human capital ranks next to technology with respect to the strength of its correlation to labour productivity.

Employee compensation according to team performance correlates significantly positive with productivity via positive employee incentives. Finally, part-time work and – rather unexpectedly – annual flexible working time have negative correlations to firm performance. Part-time work is still not particular popular among Swiss personnel managers and numerical labour flexibility is not the device typically applied to enhance productivity. The typical career of a well-qualified male employee is mostly, even in the nineties, based on a full-time job; part-time work remained primarily the domain of low-skilled persons.

In sum, we found significant positive correlations for many of the single variables belonging to the three main variable blocks (technology, organisation and human capital); the strongest effects are traced back to technology, the proxies for human capital are somewhat weaker than those for technology, the organisational variables show the weakest relation to productivity.[5]

9.7 Results for the "compact" model

The estimates of the two versions of the "compact" model are presented in Table 9.7: column 1 contains the results for the version with the standardised variables, column 4 the results for the version based on the factor scores. In both versions all three composite indices for technology, organisation and human capital have significant positive coefficients and the relative importance with respect to labour productivity measured by the magnitude of the regression coefficients of these three variables leads to the same ranking of the three factors as in the basic model: technology at the first position, then human capital, at the end organisational factors.

The compact version of the productivity model considerably facilitates the investigation of the important question of endogeneity of some of the independent variables which are the focus of this study, namely technology and organisation. It is of course not possible to settle this matter definitely based only on cross-section data. However, some hints with respect to the robustness of the cross-section estimates can be gained through 2SLS estimates of the productivity equation. In the first stage the variables TECHNS and ORGANS were instrumented, the first stage estimates are shown in columns 2 and 3 of Table 9.8. As instruments we used in both cases besides the dummy variables for part-time work, annual flexible working time and team compensation, six firm size dummies and three additional dummy variables not included in the productivity model. These refer to employee competence for the sequence of performing tasks, employee competence for the way of performing tasks and for the possibility of investment decisions being discussed in teams.[6] The overall statistical fit of the two first stage estimates for TECHNS and ORGANS, particularly for ORGANS ($R^2 = 0.068$), was rather poor. The 2SLS estimates in column 1 of Table 9.8 showed that the effect of TECHNS had been rather underestimated in the model version without instruments, that of the variable ORGANS becomes statistically insignificant (at the test level of 10%). In the face of this evidence the importance of the organisational factors has to be somewhat reconsidered; on the other hand the 2SLS estimates have to be viewed with caution because of the difficulty in estimating statistically satisfactory instrument equations with the available data.

5. We conducted some additional probit estimations of the basic model not presented here with the discretionary variables "introduction of innovations in the period 1998-2000 yes/no", "introduction of product innovations in the period 1998-2000 yes/no" and "introduction of process innovations in the period 1998-2000 yes/no") as dependent variables. We obtained similar results for the technology and human capital variables. Team-work was significant only for process innovations, overall delegation of competencies from managers to employees for all three innovation variables.

6. These three variables we also used as independent variables in earlier versions of the basic model, but they correlated very weakly with the performance variable.

Table 9.8. **Compact model: average labour productivity (log(sales per employee), 1999[1]) – 2SLS estimates of the model version with composite indices for technology, organisation and human capital based on standardised values; TECHNS and ORGANS are instrumented**

Explanatory variables	(1)	(2)	(3)
	2 SLS estimate	First stage estimates	
		TECHNS	ORGANS
Intercept	5.571***	0.127	-0.838***
	(0.080)	(0.352)	(0.557)
Log(mat/employee)[1]	0.777***		
	(0.056)		
TECHNS[2]	1.094**		
	(0.448)		
ORGANS[3]	0.236		
	(0.310)		
HUMANS[4]	0.633***		
	(0.085)		
Team compensation[5]	0.488	0.128	0.594***
	(0.344)	(0.086)	(0.137)
Part-time work[6]	-0.728**	0.088	-0.005
	(0.334)	(0.095)	(0.150)
Flexible working time[7]	-0.634**	0.042	0.201
	(0.298)	(0.083)	(0.132)
Investment decisions are discussed in teams[8]		0.423***	0.454***
		(0.106)	(0.168)
Employees' competence for the sequence of performing tasks[9]		0.267**	0.823***
		(0.111)	(0.175)
Employees' competence for the way of performing tasks[9]		0.007	0.751***
		(0.108)	(0.171)
Firm size:			
20-49 employees		-0.282	-0.077
		(0.298)	(0.472)
50-99 employees		0.107	-0.135
		(0.300)	(0.475)
100-199 employees		0.257	0.049
		(0.302)	(0.479)
200-499 employees		0.475	0.041
		(0.306)	(0.485)

(continued on next page)

Table 9.8. **Compact model: average labour productivity (log(sales per employee), 1999[1]) – 2SLS estimates of the model version with composite indices for technology, organisation and human capital based on standardised values; TECHNS and ORGANS are instrumented** *(continued)*

500-999 employees		0.656	0.069
		(0.341)	(0.540)
> 999 employees		0.446	0.303
		(0.353)	(0.559)
N	1 382	1 382	1 382
DF	34	39	39
SER	0.506	1.455	2.306
F	35.6***	9.8***	3.6***
R^2adj.	0.461	0.200	0.068

1. Number of employees calculated in full-time equivalents.
2. Sum of the standardised variables for user intensity of Internet and Intranet (two variables measured on a five-point Likert scale).
3. Sum of the standardised variables for work place organisation (six dummies for: job rotation; team work; decrease of the number of managerial levels since 1995; overall delegation of (not further specified) competences from managers to employees since 1995; employees have at the workplace level the competence to solve autonomously emerging *production problems*; employees have at the workplace level the competence to contact autonomously *customers*).
4. Sum of the standardised variables for human capital (three variables: share of employees with high education; share of employees receiving job-related training; dummy variable for computer training).
5. Dummy variable (value 1 for firms reporting that employee compensation according to *team performance* is “important” (values 4 and 5 on a five-point Likert scale)).
6. Dummy variable (value 1 for firms reporting that *part-time work* is “important” (values 4 and 5 on a five-point Likert scale)).
7. Dummy variable (value 1 for firms reporting that *flexible annual working time* is “important” (values 4 and 5 on a five-point Likert scale)).
8. Dummy variable (1 for firms reporting that investment decisions are “often” discussed in work teams (values 4 and 5 on a five-point Likert scale)).
9. Dummy variables (value 1 for firms reporting that at the workplace level employees have the competence for determining the *sequence of performing tasks* (the *way of performing tasks*) (values 4 and 5 on a five-point Likert scale)); estimations include also two-digit industry controls (27 dummies); ***, **, * denote statistical significance at the 1%, 5% and 10% level respectively.

9.8 Complementarities

We investigated the complementarities of technology, organisation and human capital with respect to labour productivity in the framework of a production function by using several approaches (see Athey and Stern 1998 for a thorough discussion).

First, we investigated the correlations between the three variables for technology, organisation and human capital in both versions, conditional on some other variables, by estimating an OLS regression for every composite variable using the other two as right-hand variables together with controls for industry and firm size (see Table 9.9). A positive coefficient of the right-hand variables would indicate a positive correlation with the left-hand variable which could be interpreted as a sign for the existence of complementarities. Using TECHNS as a dependent variable leads to positive coefficients for ORGANS and HUMANS of which only the coefficient of HUMANS is statistically significant (see column 1 of Table 9.9). When TECHNF is the dependent variable the coefficients of the other two variables are positive and significant but the coefficient of ORGANF is very small, about a seventh of the coefficient of HUMANF (see column 3 in Table 9.9). The estimates for

HUMANS and HUMANF as dependent variables showed that the correlation between the human capital and the technology variables is much stronger as the correlation between the human capital and the organisation variable. In sum, there is evidence for a strong positive relation between human capital and technology and a much weaker one between these two variables and organisation, whereas the relation of organisation to human capital is somewhat stronger that that to technology.

Second, we inserted in both versions of the "compact" model in Table 9.7 interaction terms of the three composite variables for technology, organisation and human capital which are considered as metric variables (column 2: TECHNS*ORGANS, TECHNS*HUMANS, ORGANS*HUMANS for the version with the standardised variables; column 5: TECHNF*ORGANF, TECHNF*HUMANF, ORGANF*HUMANF for the version with the factor scores). In both cases we found that only the coefficient of the interaction term of the technology variable with the human capital variable is positive and statistically significant. This result can be interpreted as a sign for the existence of complementarities between ICT and human capital, which means that the combined use of ICT and human capital in a firm would enhance its performance beyond the direct effects of these factors taken alone.

Third, we studied the question of complementarities in the framework of the basic model which contains almost only discrete variables. For concrete variables it is not possible to build an interactive term by multiplying the two variables. All three blocks of variables contain mainly binary (0,1) variables with the exception of the shares of employees with high education and training in the human capital variable block which can easily transformed to binary variables. As briefly discussed in section 9.2, complementarities of individual practices such as having team-work, training programmes, use of Internet, etc. can be formulated as a parametric restriction on the production function which leads to the following test statistic for complementarities between two practices: $\beta_{11} - \beta_{01} - [\beta_{10} - \beta_{00}] > 0$, whereby the β's are the coefficients of a series of four possible "states" of combined activity in form of dummy variables: (1,1), (0,1), (1,0), (0,0). For example if one practice is team-work and the second one a certain percentage of employees using Intranet, there are four possible combinations of these two activities: team-work and Intranet use, no team-work and Intranet use, team-work and no Intranet, no team-work and no Intranet.

We decided to test this restriction for the activities "use of Internet by employees" (0: up to 20% of employees; 1: more than 20% of employees), "use of Intranet by the employees", (0: up to 40% of employees; 1: more than 40% of employees); "intensity of use of team-work" (see dummy variable for team-work), "use of human capital" (0: share of employees with high education up to 10%; 1: more than 10% of employees with high education) (see also note to Table 9.10). In this way we test the existence of complementarities between team-work and Internet use ("states" s_{11}, s_{12}, s_{13}, s_{14} in Table 9.10), team-work and Intranet use ("states" s_{21}, s_{22}, s_{23}, s_{24}), team-work and employee high education ("states" s_{31}, s_{32}, s_{33}, s_{34}), Internet use and employee high education ("states" s_{41}, s_{42}, s_{43}, s_{44}) and Intranet use and employee high education ("states" s_{51}, s_{52}, s_{53}, s_{54}). The coefficient restriction for every pair of the above-defined activities was tested separately by inserting four dummy variables for the four possible combinations of these activities in the productivity equation. The results are presented in Table 9.10. The coefficients of the "states" (1,1) are positive and statistically significant (test level of 10%) for every pair of activities taken into consideration. The complementarity condition is fulfilled only for the activities "use of Internet" and "use of human capital" and "use of Intranet" and "use of human capital". This approach also leads to the same result as in the second paragraph of this section: if complementarities with respect to labour productivity exist, they exist between ICT and human capital; organisational factors do correlate positively directly to productivity, but no synergy effects with ICT and human capital could be traced for the firm sample used in this study.

Table 9.9. **Relations among the variables TECHNS(F), ORGANS(F) AND HUMANS(F) – OLS estimates of simple factor equations**

	Dependent variables:			
Independent variables	TECHNS	HUMANS	TECHNF	HUMANF
Intercept	0.575	-0.507	0.267	-0.267
	(0.352)	(0.371)	(0.168)	(0.172)
ORGANS[1]	0.011	0.100***		
	(0.015)	(0.018)		
HUMANS[2]	0.255***			
	(0.022)			
TECHNS[3]		0.300***		
		(0.027)		
ORGANF[4]			0.046**	0.125***
			(0.019)	(0.022)
HUMANF[5]			0.335***	
			(0.024)	
TECHNF[6]				0.393***
				(0.028)
N	1 518	1 518	1 518	1 518
DF	35	35	35	35
SER	1.461	1.584	0.711	0.771
F	16.6***	16.9***	26.6***	22.7***
R^2adj	0.265	0.268	0.371	0.328

1. Sum of the standardised variables for work place organisation (six dummies for: job rotation; team work; decrease of the number of managerial levels since 1995; overall delegation of (not further specified) competences from managers to employees since 1995; employees have at the workplace level the competence to solve autonomously emerging *production problems*; employees have at the workplace level the competence to contact autonomously *customers*).
2. Sum of the standardised variables for human capital (three variables: share of employees with high education; share of employees receiving job-related training; dummy variable for computer training).
3. Sum of the standardised variables for user intensity of Internet and Intranet (two variables measured on a five-point Likert scale).
4. Factor scores of a one-factor solution of principal component factor analysis of the six variables for workplace organisation mentioned in note (1) above.
5. Factor scores of a one-factor solution of principal component factor analysis of the three variables for human capital mentioned in note (2) above.
6. Factor scores of a one-factor solution of principal component factor analysis of the two variables for information technology mentioned in note (3) above; estimations include also two-digit industry controls (27 dummies) and firm size controls (six dummies); ***, **, * denote statistical significance at the 1%, 5% and 10% level respectively; heteroscedasticity robust standard errors (White procedure).

Table 9.10. **Tests for complementarities between technology, organisation and human capital (in pairs) with respect to average labour productivity – OLS estimates for log(sales per employee), 1999**

Explanatory variables	(1)	(2)	(3)	(4)	(5)
Intercept	5.151***	5.201***	5.365***	5.318***	5.276***
	(0.177)	(0.155)	(0.148)	(0.144)	(0.148)
Log(materials/employee)	0.768***	0.747***	0.773***	0.759***	0.747***
	(0.247)	(0.244)	(0.249)	(0.245)	(0.244)
Technology:					
Use of Internet (% of employees):					
1-20	0.070*		0.064		0.027
	(0.041)		(0.041)		(0.042)
21-40	0.143***		0.134***		0.095*
	(0.052)		(0.050)		(0.051)
41-60	0.188***		0.202***		0.154**
	(0.068)		(0.063)		(0.065)
61-80	0.345***		0.331***		0.279***
	(0.082)		(0.078)		(0.076)
81-100	0.310**		0.314***		0.215**
	(0.118)		(0.108)		(0.105)
Use of Intranet (% of employees):					
1-20		0.135***		0.134***	0.130***
		(0.042)		(0.040)	(0.041)
21-40		0.207***		0.191***	0.192***
		(0.047)		(0.045)	(0.045)
41-60		0.214***		0.211***	0.207***
		(0.047)		(0.046)	(0.046)
61-80		0.199***		0.188***	0.172***
		(0.051)		(0.049)	(0.050)
81-100		0.393***		0.388***	0.362***
		(0.076)		(0.070)	(0.069)
Workplace organisation:					
Team-work			0.080**	0.086**	
			(0.037)	(0.036)	
Job rotation	-0.070	-0.078	-0.059	-0.067	-0.056
	(0.076)	(0.074)	(0.075)	(0.073)	(0.074)
Delegation of competence from managers to employees:					
Overall transfer of competence from managers to employees	0.000	-0.016	0.003	-0.010	-0.005
	(0.027)	(0.027)	(0.026)	(0.026)	(0.025)
Employees competence to solve production problems	0.111	0.100	0.112	0.108	0.114
	(0.086)	(0.084)	(0.085)	(0.084)	(0.085)
Employees competence to contact customers	0.118***	0.115***	0.106***	0.102***	0.103***
	(0.037)	(0.037)	(0.036)	(0.036)	(0.035)
Decrease of number of managerial levels	0.021	0.016	0.030	0.031	0.021
	(0.066)	(0.064)	(0.062)	(0.061)	(0.062)
Human capital:					
Share of employees with high education	0.333***	0.301***			
	(0.110)	(0.114)			
Share of employees receiving job-related training	0.147**	0.129**	0.132**	0.115**	0.111**
	(0.063)	(0.063)	(0.055)	(0.055)	(0.055)
Computer training	0.071**	0.059**	0.062**	0.052**	0.052*
	(0.029)	(0.028)	(0.027)	(0.027)	(0.027)
Compensation, working conditions:					
Team compensation	0.065**	0.069**	0.062**	0.064**	0.062**
	(0.029)	(0.029)	(0.028)	(0.028)	(0.028)

(continued on next page)

Table 9.10. **Tests for complementarities between technology, organisation and human capital (in pairs) with respect to average labour productivity – OLS estimates for log(sales per employee), 1999** *(continued)*

Part-time work	-0.063*	-0.063**	-0.068**	-0.070**	-0.071**
	(0.032)	(0.032)	(0.031)	(0.031)	(0.030)
Flexible working time	-0.050*	-0.052**	-0.046*	-0.050*	-0.048*
	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)
"States":					
s_{i1}	0.270**	0.170**	0.074	0.061	0.111**
	(0.126)	(0.076)	(0.048)	(0.048)	(0.046)
s_{i2}	0.267**	0.187**	0.019	0.017	0.062
	(0.117)	(0.077)	(0.050)	(0.056)	(0.068)
s_{i3}	0.177	0.076	-0.014	-0.020	-0.009
	(0.116)	(0.070)	(0.046)	(0.046)	(0.044)
s_{i4}	0.332***	0.248***	0.208***	0.221***	0.192***
	(0.122)	(0.089)	(0.052)	(0.053)	(0.059)
F test [H_o : coeff.(s_{i3})+coeff.(s_{i4})-(coeff.(s_{i1})-coeff.(s_{i2})=0]; (column i: =1,...5]:					
F value	0.1	0.2	3.7	4.5	0.0
p	0.713	0.649	0.059	0.034	0.896
N	1 382	1 382	1 382	1 382	1 382
DF	48	48	48	48	48
SER	0.498	0.495	0.490	0.487	0.486
F	27.7***	28.2***	29.6***	30.2***	28.1***
R^2adj.	0.480	0.486	0.484	0.490	0.491

Column (1):

s_{11}: Dummy for *team-work* = 1; dummy for use of *Intranet* = 0
s_{12}: Dummy for *team-work* = 0; dummy for use of *Intranet* = 1
s_{13}: Dummy for *team-work* = 0; dummy for use of *Intranet* = 0
s_{14}: Dummy for *team-work* = 1; dummy for use of *Intranet* = 1
(dummy for use of *Intranet*: 0: up to 40%; 1: more than 40% of employees)

Column (2):

s_{21}: Dummy for *team-work* = 1; dummy for use of *Internet* = 0
s_{22}: Dummy for *team-work* = 0; dummy for use of *Internet* = 1
s_{23}: Dummy for *team-work* = 0; dummy for use of *Internet* = 0
s_{24}: Dummy for *team-work* = 1; dummy for use of *Internet* = 1
(dummy for use of *Internet*: 0: up to 20%; 1: more than 20% of employees)

Column (3):

s_{31}: Dummy for human capital = 1; dummy for use of Intranet = 0
s_{32}: Dummy for human capital = 0; dummy for use of Intranet = 1
s_{33}: Dummy for human capital = 0; dummy for use of Intranet = 0
s_{34}: Dummy for human capital = 1; dummy for use of Intranet = 1
(dummy for human capital: 0: share of employees with high education up to 10%; 1: more than 10% of employees with high education); dummy for use of Intranet: 0: up to 40%; 1: more than 40% of employees)

Column (4):

s_{41}: Dummy for human capital = 1; dummy for use of Internet = 0
s_{42}: Dummy for human capital = 0; dummy for use of Internet = 1
s_{43}: Dummy for human capital = 0; dummy for use of Internet = 0
s_{44}: Dummy for human capital = 1; dummy for use of Internet = 1
(dummy for human capital: 0: share of employees with high education up to 10%; 1: more than 10% of employees with high education); dummy for use of Internet: 0: up to 20%; 1: more than 20% of employees)

Column (5):

s_{51}: Dummy for human capital = 1; dummy for team-work = 0
s_{52}: Dummy for human capital = 0; dummy for team-work = 1
s_{53}: Dummy for human capital = 0; dummy for team-work = 0
s_{54}: Dummy for human capital = 1; dummy for team-work = 1
(dummy for human capital: 0: share of employees with high education up to 10%; 1: more than 10% of employees with high education)

See also notes of Table 9.1 for other variables; estimations include two-digit industry controls (27 dummies); ***, **, * denote statistical significance at the 1%, 5% and 10% level respectively; heteroscedasticity robust standard errors (White procedure).

On the whole, we could find evidence only for complementarities between ICT and human capital. One reason for not being able to identify any other complementary effects may be that, as longitudinal studies show, firms using ICT for a short time (*e.g.* less than two years in the Australian case; see Chapter 6) appear to have little complementary relation with organisational changes; moreover, the impact not only of ICT use but also of complementary changes tends to fade away with the length of ICT use (see *e.g.* Gretton *et al.,* 2002 and Chapter 6).

9.9 Summary and conclusions

The basic model yielded positive coefficients for all but one of the dummy variables for the intensity of use of Internet and Intranet as measured by the share of employees using these technologies in daily work. Positive effects were also obtained for the three variables measuring human capital (share of employees with education at the tertiary level and job-related training respectively, high importance of computer training). The results for the organisational variables were mixed: positive effects for team-work and delegation of competences to employees to solve autonomously production problems (only in manufacturing) and to contact customers; negative effects of job rotation and overall delegation of competences from managers to employees in manufacturing.

We also found considerable positive correlations with labour productivity for two types of composite variables for ICT and for human capital (sum of standardised values of the single variables, factor scores of the one-factor solution of a principal component factor analysis). There was a positive effect also for the composite variables related to organisation, but it was considerably weaker as those for technology and human capital; moreover this effect became insignificant in the 2SLS estimation.

On the whole, the results for all three variable blocks seem to be quite robust across several specifications (single variables, two types of composite variables, instrumented versions).

There is also evidence for strong positive complementarities between ICT and human capital but not between these two factors and organisation (at least in the way workplace organisation was measured and specified in this study).

A comparison with other similar studies (see Table 9.11)[7] shows that most studies find a positive effect for ICT and organisation respectively, some of them also for human capital; most US studies in the Table did not find a significant positive effect for human capital. With respect to these direct effects Swiss firms tend to give more attention to human capital than to organisation relative to firms in other countries. What about complementarities? The US studies find all three possible types of complementarities between ICT, organisation and human capital to be significant; the Australian study shows the existence of complementarities primarily between ICT and human capital and – somewhat weaker – between ICT and organisation. In the European studies there is a tendency for complementarities between ICT and human capital and organisation and human capital (as in our study). The results are indicative but not completely comparable because some of the observed differences can be traced back to differences with respect to the sectors and industries covered in the studies, the specification of the organisational variables and the nature of the investigations (cross-sectional versus longitudinal).

7. The choice of the studies reported in Table 9.11 was based on the following criteria: recent date of publication, consideration of at least two of the three variable blocks technology, organisation and human capital in the model specification, firm-level analysis, coverage of all sectors of the economy.

The main shortcoming of this study is that no data were available for a longitudinal study which would allow us to take into consideration possible lags between the variables and to test causal relationships between the explanatory factors and firm performance. We hope in the future to be able to repeat the survey for 2000, so that data for an additional point in time would become available.

Finally, we make a remark about the possible policy implications of the observed complementarities between education and training and the use of ICT: if there is public support for training, education, etc., for example through subsidies, then knowledge of such complementarities is useful for policy makers because it can lead to the more effective choice and combination of policy initiatives and measures.

Table 9.11. **Summary of the empirical literature**

Study	ICT	ORG	HC	Complementarities
USA				
Black and Lynch (2000)				
– Cross-section	Positive	Positive	ns	ns
– Longitudinal	Positive	Positive	ns	ns
Capelli/Neumark (2001)				
– Cross-section	Positive	Positive	ns	ns
– Longitudinal	Positive	Positive	nc	ns
Bresnahan et al. (2002)				
– Cross-section	Positive	Positive	Positive	ORG/ICT; HC/ICT
Brynjolfsson et al. (2002)				
– Longitudinal	Positive	ns	nc	ORG/ICT
Australia:				
Gretton et al. (2002)				
– Longitudinal	Positive	Positive	Positive	ORG/ICT; HC/ICT
Germany:				
Bertschek/Kaiser (2001)				
– Cross-section	Positive	Positive	nc	ns
Wolf/Zwick (2002)				
– Longitudinal	Positive	Positive	Positive	nc
Hempell (2003)				
– Longitudinal	Positive	nc	ns	ICT/HC
France:				
Caroli/Van Reenen (1999)	ns	Positive	Positive	ORG/HC
– Longitudinal				

Notes: ICT: information and communication technologies; ORG: workplace organisation; HC: human capital; “positive”: statistically significant (at the test level of 10%) positive coefficient of the variables(s) for ICT, ORG and HC respectively; ns: statistically not significant (at the test level of 10%); nc: not considered.

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ANNEX

Table A9.1. **Composition of the dataset (basic model)**

	N	Percentage
Industry		
Food, beverage	62	4.5
Textiles	24	1.7
Clothing, leather	13	0.9
Wood processing	17	1.2
Paper	24	1.7
Printing	51	3.7
Chemicals	50	3.6
Plastics, rubber	28	2.0
Glass, stone, clay	28	2.0
Metal	15	1.1
Metal working	107	7.7
Machinery	123	9.0
Electrical machinery	33	2.4
Electronics, instruments	74	5.4
Watches	24	1.7
Vehicles	15	1.1
Other manufacturing	30	2.2
Energy, water	24	1.7
Construction	151	11.0
Wholesale trade	145	10.5
Retail trade	84	6.1
Hotels, catering	33	2.4
Transport, telecommunication	63	4.6
Banks, insurances	54	3.9
Real estate, leasing	4	0.3
Computer services	20	1.4
Business services	79	5.7
Personal services	7	0.5
Firm size:		
20-49 employees	443	32.1
50-99 employees	336	24.3
100-199 employees	278	20.1
200-499 employees	198	14.3
500-999 employees	69	5.0
> 1 000 employees	58	4.2
Total	1 382	100

TABLE OF CONTENTS

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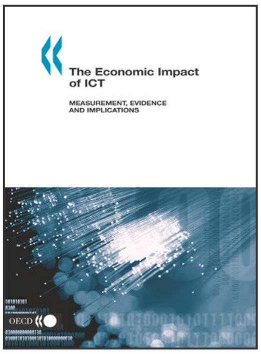

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