

Arvanitis, Spyros

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Spyros Arvanitis

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Information Technology, Workplace Organization and the Demand for Employees of Different Education Levels: Firm-Level Evidence for the Swiss Economy*

Spyros Arvanitis

Swiss Institute for Business Cycle Research (KOF)

Swiss Federal Institute of Technology (ETHZ)

ETH Zentrum

CH-8092 Zurich

Phone +411 / 632'51'68

Fax +411 / 632'10'42

E-mail arvanitis@kof.gess.ethz.ch

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1. Introduction

There is long-term empirical evidence that both the number and the employment share of high-skilled (or high-educated) workers have grown over time in many OECD countries. In the last years many prominent economists were engaged in an intensive discussion on the reasons for the observed shift of labour demand toward 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*). One of the most popular explanations which have been offered by the economic literature is based on the so-called „skill-biased technological change“ hypothesis, according to which the reason for the upskilling of labour force is the non-neutrality of technological change, which favours the use of skilled labour more than the use of other labour inputs. Due to the complementarity of skills (education) and technology, an acceleration of the rate of technological change would cause an increase of the demand for skilled labour.¹² The reason for the most recent acceleration of technological change is assumed to be the diffusion of Information and Communication Technologies (ICT) which seem to have given new impetus to the substitution process of low-skilled by high-skilled employees. Nevertheless, for some authors it is not clear, whether the observed shift of labour demand is caused mainly by within-sector technological change or by sector-biased technological change, i.e. technological change affecting only some specific sectors (see e.g. Haskel and Slaughter 2002). On the whole, the technology hypothesis cannot explain the entire magnitude of the observed labour demand shift. This is the reason why some researchers have looked for other possible alternative or complementary explanations of the change of the composition of the labour force. For trade economists such alternative explanations are related to the internationalization of economic activities (see e.g. Wood 1995),³ for industrial and managerial economists are associated with the reorganization of production which took place parallel to the introduction of ICT. The latter is the approach we are also going to pursue in this paper.

The present study explores empirically the hypothesis that ICT and new organizational practices are important determinants of the demand for labour of different skills, further that

¹ Yet it is also true that an increase in the supply of skills can also induce an acceleration of technological change; thus, it is assumed that in the long-run the driving force from the demand side is the dominant one (see e.g. Acemoglu 1998).

² Some of the most influential empirical studies on this subject in the last years are the following: for the USA: Krueger (1993); Doms et al. 1997; Autor et al. (1998); Chun (2003); for the UK: Chennels and Van Reenen (1999); Haskel and Heden (1999); für Germany: Kaiser (1999); Falk (2001); Falk and Seim (2001); for France: Goux and Maurin (2000); comparative studies for many countries: Berman et al. (1998); Machin and Van Reenen (1998). For a recent survey of the theoretical and empirical literature on skill-biased technical change see Sanders and ter Weel (2000).

³ The main hypothesis is that the accelerated growth of world trade and foreign direct investment leads to a new international division of labour: the production of goods (and services) with a high content of low-skilled labour are dislocated to developing countries of the South, while activities with a high content of high-skilled labour are concentrated in the developed countries of the North. For an exploratory study on this subject for Switzerland at firm level see Arvanitis and Donzé (2000).

the joint use of these two factors leads to a mutual strengthening of their impact on labour demand. The analytical framework is that of demand function for employees with different education levels (heterogeneous labour) at firm level. The study's new contribution to empirical literature consists in being the first empirical study of this type for Switzerland using a rich data set at firm level which were collected by means of a postal survey and giving particular attention to the complementarity issue and to the endogenization of organization. In addition, we focused to some statistical problems typically related to survey data; multiple imputations were used to substitute for missing values (problem of item non-response). 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 paper is as follows: section 2 sketches the analytical background of the paper related to new theories on the combined influence of ICT and organizational factors on labour demand. Section 3 gives descriptive information on the existence and diffusion of ICT and new organizational practices in the Swiss business sector. Section 4 contains a description of our data. In section 5 the specification of the empirical model is presented and discussed. Section 6 contains the results of the econometric estimates. A survey of similar empirical studies for other countries is presented in section 7. Finally, we summarize the main findings, indicate some directions of future research and draw some policy conclusions.

2. Conceptual Background

The „Skill-Biased Technical Change“ Hypothesis: The Role of ICT

The shift toward more highly educated workers, which can be observed since the late sixties or possibly the early seventies in many OECD countries, appears to have accelerated in the last twenty years (see e.g. Berman et al 1998, OECD 1998). 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 labour demand shift have led many observers to seek skill-biased technical change in the largest and most widespread new technology of the last years, ICT (see Bresnahan 1999, 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 computerized systems not only systematically substitute computer decision-making for human decision-making in routine work, but also produce a large quantity of data which needs high-skilled workers, managers and professionals to get adequately utilized.

The specific influence of ICT adoption and use on the composition of the workforce has been a particular subject of recent theoretical and empirical analysis. One important proposition is

that ICT capital (a) substitutes for workers performing cognitive and manual tasks that can be accomplished by following given rules and (b) complements workers in performing non-routine cognitive tasks concerning generalized problem-solving and complex communications (see Bresnahan 1999 and Autor et al. 2003). This distinction of routine and non-routine tasks leads to a further differentiation related to the possibility of different effects on the skill mix depending on the type of technology under study. In manufacturing firms with a large scope for factory automation technologies an increase of the share of high-skilled or high-educated workers may prove to be rather small in comparison to manufacturing or service firms in which computer investment is mainly related to the work of non-production workers with administrative or managerial tasks, etc. (see Doms et al. 1997).

The „Skill-Biased Organizational Change“ Hypothesis: The Role of New Forms of Workplace Organization

A further hypothesis put forward in the literature recently refers to the influence of the increasing diffusion and application of intra-firm reorganization processes on the observed change of firms' skill requirements. The basic idea is that a gradual shift from rigid „Tayloristic“ organization (characterized by specialization by tasks) to „holistic“ organization (featuring job rotation, integration of tasks and learning across tasks)“ (Lindbeck and Snower 2000, p. 353) is taking place within firms. This phenomenon first appeared in the USA and Japan and has spread later throughout Europe, although at a different pace from country to country (see Aoki 1986, Greenan and Guellec 1994).

The main elements of reorganization at the workplace level according to economic, management and sociological studies on this field are (see Caroli 2001 for a survey of the literature on this subject): (a) decentralization of decision-making by delegation of relevant competences from management to lower hierarchy levels, increased involvement and autonomy of employees at the shopfloor level; (b) new working practices such as team-work (semi-autonomous work-teams, quality circles, etc.), job rotation, other forms of multi-tasking, multi-skilling, etc.. Many authors seem to share the idea that changes in work organization towards more “holistic” structures, definitely require an upgrading of the skill content of most jobs related to these changes. Caroli (2001) presents a series of reasons for it. Current organizational changes increase employees' responsibility for tasks and operations. This is not only the case for operatives but also for supervisors and technicians, whose roles, hence skills, are considerably modified by the new organizational practices. Interpersonal abilities also become more important owing to the increasing need for communication and co-ordination. Thus, an important precondition for the successful implementation of most of these new organizational practices is the availability of a higher skilled (or higher educated) workforce.

Complementarities: Technical Change Related to Organizational Change

The use of ICT, new organizational 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“. Also for the organizational practices there exist interdependencies with other factors and inputs. Some of the changes of 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 centralized mode of firm organization in which knowledge is confined to specialized workers and a decentralized 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).

Demand Equations for Specific Labour Skills

The above discussion of the literature shows that there are some common testable hypotheses with respect to the contribution of ICT and new organizational practices to changes of the skill requirements of labour. These can be at best put together formally in a framework of demand equations for categories of employees with different skills or education containing besides factor prices and physical capital also ICT and organization capital (see Doms et al. 1997 and Machin and Van Reenan 1998):

- Hypothesis 1: there are considerable positive (negative) effects of ICT on the demand for high-educated (low-educated) employees;
- Hypothesis 2: there are considerable positive (negative) effects of new forms of workplace organization on the demand for high-educated (low-educated) employees;
- Hypothesis 3: there is a positive (negative) interrelationship between technology and organization leading to a mutual strengthening of the effects of these two factors on the demand for high-educated and low-educated employees respectively (complementarity hypothesis).

3. Descriptive Analysis

Shift of Labour Demand towards High-educated Employees in the Swiss Business Sector in the Nineties

Table 1 offers some qualitative information on the extent of the shift of the skill-mix of Swiss firms in the period 1997-2000. The difference between the percentage of firms reporting an increase and the percentage of those reporting a decrease of the employment share of

university graduates in the period 1997-2000 was 4.7%, for employees with education at the tertiary level this percentage was 15.7% and for employees with a vocational education ending with a formal degree 5.6%. Of course for such a rather short period for most firms remained these shares unchanged. For all three employee categories we observe at the balance an increase of the corresponding employment shares; the extent of this increase is not the same for all categories. On the contrary, the overall change was negative for low-educated employees (vocational education without a formal degree / no vocational education), 18.2 of all firms reported a decrease of the employment share of this employee group, only 9.4% an increase; at the balance, 8.8% of all firms reduced the share of low-educated employees. The differences among sectors (manufacturing, construction, services) are not so large, the direction and extent of the shifts are quite similar all over the economy. Table 2 shows the educational composition of employed labour of the firms in our sample.

Use of ICT and New Organizational Practices

Between 1995 and 2000 as in many other OECD countries the use of information technologies in Swiss business sector has increased at a tremendous rate. We concentrate here on internet and intranet, both of them technologies which permit a high degree of networking among various firm activities. 81.3% of manufacturing firms used in the year 2000 internet, almost as frequent as firms in the service sector (79.5%) but significantly more often than construction enterprises (69.4%) (see table 3). On the whole 27.0% of firms used in 2000 an internal network (intranet); 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%).

The intensity of use of new technology inside a firm may prove to be more important with respect to a firm's skill-mix than the mere incidence of ICT. Table 3 presents also some information on the percentage of employees using internet and intranet respectively. On the average, 28.6% of the employees of all firms applying this technology used in 2000 internet 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 the 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).

Tables 3 and 4 present some information on the incidence of several new organizational practices in the Swiss business sector which can influence a firm's skill-mix, mostly in the context of an intensive use of ICT. Two main forms of new workplace organization are team-working (work in formally organized project groups, teams, quality circles, semi-autonomous groups, etc.) and job rotation. According to table 3, 35.7% of Swiss firms had introduced team-working, 10.4% of them job rotation. There are significant differences with respect to the incidence of these two practices in the manufacturing and the service sector,

manufacturing firms using considerably more team-work and job rotation than service and construction firms. 20.8% of all firms, i.e. 58.3% of firms with team-work, use this organizational practice intensive, for job rotation the corresponding figures are 4.2% and 40.4% respectively (table 3). There are no significant differences among the sectors with respect to the intensity of use of these two organizational practices.

As the data in table 4 show, the number of managerial levels did not change much between 1995 and 2000 for firms in all sectors of the economy; 9.4% of firms reported a decrease, 4.8% an increase, on the balance only 4.6% of all firms flattened their hierarchical structure in this period. The same table contains also data on the overall shift of competences from managers to employees in the period 1995-2000: 40.0% of all firms reported such a shift; this figure was somewhat higher in manufacturing (48.5%), approximately the same in the service sector (42.4%) and considerably lower in the construction industry (21.2%).

4. Data

The data used in this study were collected in the course of a 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 organizational practices (team-work, job rotation, employees' involvement, etc.), employees' vocational education, flexibility of working conditions and labour compensation schemes.⁴ 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 (on the whole 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, i.e. 39.4% of the firms in the underlying sample.⁵ 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 A.1 in the appendix 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 organizational practices (team-work, job rotation). A careful examination of the data of these 1667 firms led to the exclusion of 123 cases with contradictory or non-plausible answers; there remained 1544 valid answers which were used for the econometric analysis.

⁴ The questionnaire was based to a considerable extent on similar questionnaires used in earlier surveys (see EPOC 1997, Francois et al. 1999, Vickery/Wurzburg 1998, Canada Statistics 1999). Versions of the questionnaire in German, French and Italian are available in www.kof.ethz.ch.

⁵ The descriptive analysis of the data presented in tables 1, 2, 3 (with respect to ICT use) in section 3 was based on a sample of 2648 firms with at least 5 employees. The information on organization was raised only for firms with at least 20 employees (sample of 1667 firms; tables 3 (with respect to the organizational practices) and 4). As a consequence, we could use data for 1667 firms for the econometric 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). The estimations were based on 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 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. This comparison showed relatively high robustness of the estimated parameters.

5. Model Specification and Variable Construction

We considered in this study three categories of employees: high-educated (employees with education at the tertiary level including universities, technical and business colleges), middle-educated (employees with a formal degree in vocational education) and low-educated (employees with some vocational education but without a formal degree or without any formal vocational education). The employment share for each of these categories was used as a dependent variable in our model estimations (equations for employment share). We also disposed of ordinal variables measuring the change of the employment share of each of these categories in the period 1997-2000. The original five-point Likert scale (1: 'very strong decrease'; 5: 'very strong increase') of these ordinal variables was transformed to a binary variable (1: 'increase', corresponding to the values 4 and 5 of the original variable; 0: 'no change/decrease', corresponding to the values 1, 2 and 3 of the original variable). These three binary variables were also used as dependent variables (equations for increase of employment share).

Since we did not dispose of data on physical capital and wage data for each education category, we relied on extensive industry controls to seize the influence of this important variable.⁶

As measures for technology input, particularly ICT input ('ICT capital'), we used the intensity of use of two important network technologies, internet (linking to the outside world) and intranet (linking within the firm). This intensity was 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 5). The idea behind this variable is that a measure of the diffusion of a certain technology within a firm would be

⁶ In case of wage data and their use as factor prices a further problem is their endogeneity which could cause serious econometric problems; some authors even proposed to omit altogether wage data in an one-equation framework (see e.g. Machin and Van Reenen 1998).

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 installed personal computers, etc.). We expect in general a positive correlation of technology variables with the (change of) employment share of high-educated employees, in particular an increasing positive correlation with a higher percentage of employees using a certain technology. A further hypothesis is that technology variables correlate negatively with the (change of) share of low-educated employees. We have no a priori expectation for the relation between technology variables and the (change of) employment share of middle-educated employees.

The measurement of organizational inputs, here restricted to inputs related to workplace organization, is an issue still open to discussion, since there is not yet any agreement among applied economists to the exact definition of „organizational capital“ (see Black/Lynch 2002 and Lev 2003 for a discussion of this matter). In order to choose the variables related to changes and/or introduction and use of new organizational practices at the workplace level we draw on the definition offered by Black and Lynch (2002). They distinguished two components of organizational capital (in a narrow sense, that is 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 organizational 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 enabled 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 determine the sequence of performing tasks and / or the way tasks are performed; investment decisions being often discussed in work teams (see also note to table 5). We expect an overall positive correlation of organizational variables with average labour productivity, but we do not have sign expectations for every single variable.

We include three more variables which are related to workplace organization but are not components of organizational 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. The other two variables measure labour flexibility (dummy variable for the intensive use of part-time work) and working time flexibility (dummy variable for working time considered flexible over the year). With respect to the compensation variable the sign of the correlation to the dependent variable is not a priori clear for middle- and low-educated employees; we expect that team compensation is considered as more adequate

and/or is more often used for higher- than lower-qualified employees. The relation between part-time work and education level of the employees is in the empirical literature not clear and depends on the overall conditions of the labour market as well as its institutional framework. We expect a positive effect for flexible yearly working time for all three employee categories; this type of labour flexibility does not only expand employee time sovereignty but also contributes to a more efficient combination of labour and equipment.

We use extensive controls for firm size (5 dummies) and industry affiliation (27 dummies) to account for firm- or industry-specific influences not taken explicitly into consideration.

In a second model version we constructed composite indices for the ICT and the organizational capital. These indices were calculated as a sum of the standardized values (average 0; standard deviation 1) of the constituent 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 standardization procedure; the organizational variable (ORGANS) was constructed as a sum of the standardized values of the seven constituent variables.⁷ The use of these composite variables as overall measures of technology and organization enabled us not only to assess the relative importance of these factors with respect to employee education but also to test the possible endogeneity of the organizational factors as well as the postulated complementarity between technology and organization.

6. Results of the Model Estimations

6.1 Equations for Employment Share

Table 5 contains the OLS estimates of the full model for the employment shares of the high-, middle- and low-educated employees.⁸ Since these results are only cross-section estimates, it is not possible to test directly the existence of causal relations between the independent variables and the dependent variable. Nevertheless, some robust regularities come out, which if interpreted in view of our hypotheses 1 to 3 (see section 2) could possibly indicate the direction of causal links.

Technological Factors

The coefficients of four of the five dummy variables for the intensity of use of internet are, as expected, positive and statistically significant in the equation for the employment share of high-educated employees, negative and statistically significant in the equation for the low-

⁷ We obtained similar results also with a further version of a composite variable for organizational capital based on the factor scores of a one-factor solution of principal component factor analysis of the seven variables for workplace organization.

⁸ There are 84 observations with the value 0 in case of the high-educated, 18 observations in case of the middle-educated and 139 in case of the low-educated employees. Tobit estimates taking account of this peculiarity of the data yielded almost identical results with the OLS estimates for all three dependent variables.

educated employees; for the category of middle-educated employees these four coefficients are positive but not statistically significant (at the test level of 10%). Only the coefficient for the lowest intensity category of internet (1%-20% of employees using internet in their daily work) is not significant in any of the three equations. The general tendency is that the higher the intensity of use of these technologies among employees, the higher (lower) in case of the high-educated (low-educated) employees is also the positive (negative) correlation to employment share.

The same effects are found qualitatively also for the intensity of use of intranet. In this case the positive correlation to the share of the high-educated employees seems to be weaker than in case of internet; only the coefficients for the variables for high intensity of intranet use (over 60% of employees using this technology in their daily work) are statistically significant.

The estimates for the composite variable TECHNS (instead of the detailed information on internet and intranet use) in table 7 show once more clearly that the technological factors correlate positively with the share of high-educated employees and negative with the share of low-educated employees; technology is not discernibly related to the employment share of the middle-educated employees.

On the whole, the results for the variables for the ICT use are quite in accordance with hypothesis 1 of skill-biased technological change.

Organizational Factors

Job rotation and the decrease of the number of managerial levels, both of them associated to the „work design“ component of organizational capital, do not seem to be significantly correlated to the employment mix with respect to different education levels. In all three equations the coefficients of these two variables are not statistically significant.

Closely related to employees' education mix are various dimensions of „employee voice“. Team-work is positively (negatively) correlated to the employment share of high-educated (low-educated) employees; we could not find a statistically significant relation of the variable for this type of organizational practice to the share of middle-educated employees. Further, we obtained statistically significant positive coefficients for the variables for high employee competence to determine the sequence and the way of performing tasks, also for the variable for frequent discussions of investment decisions in work-teams in the equation for the share of high-educated. On the contrary, we found statistically significant negative coefficients for team-work and high employee competence for the way of performing tasks in the equation for the share of low-educated employees. For one organizational variable, high employee competence for the way of performing tasks, the estimates yielded a significant positive coefficient also in the equation for the share of middle-educated. There is no indication of significant effects for the overall delegation of competences from managers to employees in any of the three employment share equations.

The estimates for the composite variable ORGANS in table 7 summarize the results with respect to the organizational factors. There is a clearly positive effect for the high-educated employees and a negative but not statistically significant effect for the low-educated employees. Also for the middle-educated employees could not be found any significant effect.

Endogeneity of Organization

The construction of a composite variable for the organizational factors facilitates considerably the investigation of the important question of the endogeneity of organization (see Athey and Stern 1998). It is of course not possible to settle definitely this matter based only on cross-section data, but some hints with respect to the robustness of the cross-section estimates can be gained through 2SLS estimates of the employment share equations. In the first stage the variable ORGANS was instrumented, the first stage estimates are shown in column 4 of table 9. As instruments we used besides the dummy variables for part-time work, yearly flexible working time, team compensation and firm size three additional variables which were not included in the employment share model: the coincidence of innovative activities, the export share of sales and a dummy variable for foreign ownership. The overall statistical fit of the first stage estimates for ORGANS ($R^2=0.092$) was rather poor. The 2SLS estimates in columns 1 and 3 of table 9 for high- and low-educated employees respectively confirm the results of the model estimates without instruments, at least with respect to the signs of the coefficients. The coefficient of ORGANS in the equation for the middle-educated becomes negative and statistically significant at the test level of 10%; in view of the rather poor performance of the instrument equation for ORGANS this result is not very robust.

On the whole, hypothesis 2 (skilled-biased organizational change) seems to be confirmed by these results.

Complementarity Effects

The equations for the employment shares in table 7 contain besides the composite variables TECHNS and ORGANS also the interaction term TECHNS*ORGANS. The coefficient of the interaction term in the equation for the high-educated employees is positive and statistically significant, in the equation for the low-educated employees negative and also statistically significant, in the equation for the middle-educated employees negative but statistically insignificant. The results can be interpreted as a hint for the existence of complementarity of ICT and workplace organization, which means that besides the direct effects of ICT and organization on the employment shares of high- and low-educated employees also exist indirect effects which can be traced back to the joint impact of these two factors on the employment shares. Hypothesis 3 receives some support from these results.

Other Factors

The variable for part-time work correlates positively with the share of high-educated employees and negatively with the share of low-educated employees; the variable for flexible

working time also correlates with the shares of high- and low-educated but with exactly opposite signs (table 5). These results reflect the relative importance of various dimensions of quantitative labour flexibility for different employee categories. Seemingly, part-time work is considered adequate primarily for low-educated employees, flexibility of working time primarily for high-educated. Also compensation according to team-performance is relevant only for the high-educated employees. Compensation and working conditions are not related to the employment share of middle-educated.

Finally, firm size correlates negatively with the share for middle-educated and positively (up to 500 employees) with the share of low-educated employees; it does not correlate at all with the share of high-educated employees. The larger a firm is, the higher is also the share of low-educated (up to 500 employees) and lower the share of middle-educated employees.

6.2 Equations for Increase of Employment Share

Table 6 contains the probit estimates of the full model for the increase of the employment shares of the high-, middle- and low-educated employees in the period 1997-2000.⁹

Technological Factors

The effects of the variables for the use of internet in the equation for the high-educated and the low-educated employees respectively in table 6 were considerably weaker than those for the corresponding level equations in table 5. There are no differences between the estimates in table 5 and those in table 6 for the middle-educated employees. We conclude that the use of internet correlates closely to the level of the employment share of high- and low-educated employees, but this effect becomes weak if we consider the change of these employment shares. We found qualitatively the same results for all three share equations with respect to the variables for the intensity of use of intranet. Thus, the shift of the employment shares observed in the period 1997-2000 was presumably driven, among other things, by the technological effects of intra-firm electronic communication via intranet.

For the composite variable ORGANS we obtained a clearly positive effect for the high-educated and a clearly negative effect for the low-educated employees in accordance with hypothesis 2 (table 8). As in table 5 for the level equation, we could not find also in this case a statistically significant effect of TECHNS in the equation for the middle-educated employees.

Organizational Factors

The positive coefficients of the variables for team-work and high employee competences with respect to the sequence and way of performing tasks are not (any more; see table 5) statistically significant in the equation for the increase of the employment share of high-educated employees in table 6. On the other hand, the positive coefficients of two other

⁹ We present in the tables only the standardized coefficients and leave out the marginal effects which (also) cannot be easily interpreted when the independent variables are dummies.

variables are statistically significant in this case (but not in table 5): those of the variable for the overall shift of competences from managers to employees and the variable for the reduction of the number of managerial levels. Thus, when the results in tables 5 and 6 are compared there is a shift of relevance from the variables for clear-targeted delegation of specific competencies from managers to employees to the variable for the overall delegation of competences. In addition, the flattening of firm hierarchy through the reduction of the number of managerial levels seems to be positively correlated with an increase of the share of high-educated employees, an effect which was not observed in the level equation in table 5. The extent of job rotation was also for the change of employment shares of small relevance.

There are no differences between table 5 and 6 with respect to the estimates for the middle-educated employees (with the exception of a positive effect of the variable for the reduction of the number of managerial levels in table 6).

For the low-educated we observe an overall weakening of the effects of the variables for employee competences but also additional positive effects of one of the employee competence variables and of the structural variable for the number of managerial levels.

The coefficient of the composite variable ORGANS is positive and statistically significant in the equation for the high-educated employees but insignificant in the other two equations (table 8). Thus, hypothesis 2 is only partly confirmed by the results in table 8.

Other Factors

Most of the effects with respect to compensation and working conditions are not any more statistically significant in table 6. Also the size effects in the equations for the middle- and the low-educated employees disappear in table 6. On the other hand, the dummies for firm size correlate positively with the increase of the share of the high-educated employees.

Complementarities

The estimates in table 8 show that the positive complementarity of technology and organization holds also for the increase of the share of high-educated employees. On the contrary, in this case the negative complementarity for the low-educated employees is not supported by the empirical evidence.

In sum, the estimates for levels as well as for changes of the employment show similar patterns: positive effects for technology and organization for the high-educated, negative effects for the low-educated (whereas the organization effect is rather weak in this case), no significant effects for the middle-educated.

7. Comparative Evidence and Survey of Empirical Literature

A comparison with other similar studies (see table 10)¹⁰ shows that there are considerable differences among the firm samples of the countries under scrutiny. The German studies are particularly relevant for this comparison because they also cover the case of middle-educated employees possessing a vocational degree from the “dual apprenticeship system” which is similar to this in Switzerland. Positive effects for both the technological and the organizational factors for the high-educated are also found in all surveyed German studies. Interaction terms for organization and technology were investigated in some cases but no statistically significant effects could be identified. The results for the middle-educated employees were mixed for both the technological and the organizational factor. On the whole, it seems that the employment of the German middle-educated employees is stronger affected from technological and organizational change than this of the corresponding Swiss employees (see also Jacobebbinghaus and Zwick 2001). For low-educated employees in most studies are found similar results as in case of Swiss firms but the effects, particularly those associated with the ICT use, seem to be weaker than those for Switzerland. Interaction terms were in most cases statistically insignificant.

For French and Italian firms the influence of technology on the employment shares of employees with different skills or education is less important than that of organization. Most studies could not find any discernible effects of technology. With respect to organizational factors there is a tendency for a positive impact for the high-educated and a negative one for the low-educated employees, in accordance with the Swiss results. Interaction terms were in some cases significantly positive for the high-educated and negative for the low-educated employees.

Studies for the USA and the U.K. demonstrate clearly the expected effects of technology on the employment of high- and low-educated employees respectively. The impact of organization is less clear than that of technology, but in most cases as expected.

On the whole, 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 organizational variables and the nature of the investigations (cross-sectional versus longitudinal approach).

8. Summary and Conclusions

In this section the results are summarized and some implications for economic policy are briefly discussed; of course, the precaution with respect to the interpretation of cross-section results already mentioned in section 6 still holds.

¹⁰ The choice of the studies reported in table 10 was based on following criteria: recent date of publication, consideration of both variable blocks technology and organization in the model specification, firm-level analysis, coverage of all sectors of the economy.

The technological changes of the last ten to fifteen years, particularly those driven by the increasing adoption and use of ICT, correlated significantly with the rising skill and education requirements of Swiss enterprises. The technological factors contributed to a clearly higher employment share for high-educated employees and an equally clear lower employment share for low-educated employees. The employment share of middle-educated employees seems to be unrelated to the extent of intra-firm ICT use. These results are in agreement with the hypothesis of skill-biased technical change, also with the results of similar studies for other high-tech OECD countries.

Changes of work organization (particularly team-work and decentralization of decision-making) contributed also to an increase of the demand for high-educated employees and a decrease of the demand for low-educated employees, but these effects were weaker than those of the technology factors. Even if the results are not so robust as in case of technology, there is a discernible tendency in favour of the hypothesis of skill-biased organizational change; the estimated effects of organization were considerably weaker than those found e.g. in French studies.

A further finding was that the technology and organization effects strengthen each other (positive joint effect). This means that besides the direct impacts the changes of the employment shares of employees with different education levels were also driven by the indirect impacts of the combined use of technology and organization.

Middle-educated employees were only slightly, if at all, affected from these changes. It is not clear if this will remain so in case of a further acceleration of skill-biased technical change in the near future.

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 to be able to repeat the survey 2000 in the next future, so that data for an additional time point would become available.

Are there any implications of the results of the study for economic policy? In general, policy makers have to pay special attention to the conditions favouring the formation and growth of human capital in the economy. This does not mean that only tertiary education should be promoted. The system of the „normal“ vocational education („Berufslehre“) – which is one of the two pillars of the Swiss „dual“ education system – has to be (further) upgraded, especially with respect to the content of education. Most of the reforms which took place during the nineties were well-targeted to cover the additional skill requirements of the business sector: upgrading of technical and business colleges other than the classical universities („Fachhochschulen“), transparency with respect to the access conditions to the tertiary education system, upgrading of specific vocational degrees in technical and business professions, etc. Further, the existing – an in international comparison rather high – flexibility

of the labour market has to be maintained, also the current legal framework which permit employers to form a flexible work organization. A more difficult problem is to offer employment perspectives to low-educated persons. Additional education and/or vocational training is one way of trying to tackle this problem, but it is not a way accessible for all involved persons, particularly not for older ones. For such cases social partners and policy makers have to co-ordinate efforts for specific solutions aiming at the social integration also of this category of employees.

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Annex:

Table 1: Percentage of Firms with Decreasing, Unchanged or Increasing Shares of Employees with Different Levels of Vocational Education 1997-2000

	H1/LT	H2/LT	M/LT	L/LT
All Firms				
(1) decrease	1.9	3.7	12.2	18.2
(2) no change	91.5	76.9	70.0	72.4
(3) increase	6.6	19.4	17.8	9.4
(3)-(1)	4.7	15.7	5.6	-8.8
Manufacturing Firms				
(1) decrease	1.9	2.2	11.0	19.8
(2) no change	90.6	75.9	66.6	68.9
(3) increase	7.5	21.9	22.4	11.3
(3)-(1)	5.6	19.7	11.4	-8.5
Construction Firms				
(1) decrease	0.3	1.4	14.1	21.2
(2) no change	98.6	87.2	60.1	64.8
(3) increase	1.1	11.4	25.8	14.0
(3)-(1)	0.8	10.0	11.7	-7.2
Service Firms				
(1) decrease	1.9	5.1	13.1	16.7
(2) no change	92.0	77.4	73.1	75.5
(3) increase	6.1	17.5	13.8	7.8
(3)-(1)	4.2	12.4	0.7	-8.9

Note: H1/LT: share of employees with university education; H2/LT: share of employees with technical or business college education (tertiary level); M/LT: vocational education ending with a formal degree; L/LT: vocational education without a formal degree / no vocational education; data for 2648 firms; multiple imputations for missing values; the data were corrected for unit non-response bias and weighted in order to reflect the population of Swiss enterprises belonging to the 2-digit industries listed in table A.1.

Table 2: Formal Education of Employees in Swiss Business Sector 1999

	Manu- facturing	Con- struction	Services	Total
<i>Formal education (average share of employees):</i>				
- University	2.7	1.0	7.8	5.4
- Other tertiary-level education	12.6	10.7	16.5	14.7
- Vocational education; formal degree	45.0	52.0	44.6	44.8
- Vocational education without formal degree; no vocational education	34.9	25.5	24.2	29.0
- Persons in the process of vocational education	4.8	10.8	6.9	6.1

Note: data of 2648 firms; multiple imputations for missing values; the data were corrected for unit non-response bias and weighted in order to reflect the population of Swiss enterprises belonging to the 2-digit industries listed in table A.1.

Table 3: Incidence and Intensity of Use of ICT and New Organizational Practices 2000

	Manu- facturing	Construction	Services	Total
<i>Internet</i>				
Percentage firms using internet	81.3	69.4	79.5	78.1
Percentage of employees using internet	20.0	15.7	36.5	28.6
<i>Intranet</i>				
Percentage firms using internet	28.2	11.3	31.6	27.0
Percentage of employees Using intranet	41.7	34.9	59.4	50.7
<i>Job rotation</i>				
Percentage of firms using job rotation	17.2	5.3	8.9	10.4
Percentage of firms using intensively job rotation ⁽¹⁾	5.0	3.9	3.3	4.2
<i>Team work</i>				
Percentage of firms using team-work	44.4	31.1	33.4	35.7
Percentage of firms using intensively team-work ⁽¹⁾	20.7	16.0	22.4	20.8

(1): percentage of firms reporting value 4 or value 5 on a five-point Likert scale

Note: data of 2648 firms (internet, intranet) and 1667 firms (job rotation, team work) resp.; multiple imputations for missing values; the data were corrected for unit non-response bias and weighted in order to reflect the population of Swiss enterprises belonging to the 2-digit industries listed in table A.1.

Table 4: Changes with respect to Some Organizational Practices 1995-2000 (percentage of firms)

Change of 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 1667 firms; multiple imputations for missing values; the data were corrected for unit non-response bias and weighted in order to reflect the population of Swiss enterprises belonging to the 2-digit industries listed in table A.1.

Table 5: Full Model: Determinants of the Employment Shares of High-Educated, Middle-Educated and Low-Educated Employees 1999 (OLS estimates)

Explanatory Variables	High-educated ⁽¹⁾		Middle-educated ⁽²⁾		Low-educated ⁽³⁾	
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
Intercept	7.759** (1.858)		41.162*** (3.595)		47.909*** (4.028)	
<i>Technology:</i>						
Use of internet (% of employees) ⁽⁴⁾						
1-20	0.134 (1.043)	0.004	-0.412 (2.085)	-0.009	0.149 (2.301)	0.003
21-40	4.491*** (1.282)	0.101	0.630 (2.252)	0.012	-5.423** (2.462)	0.086
41-60	9.746*** (1.897)	0.150	0.241 (2.801)	0.003	-9.691*** (2.845)	0.106
61-80	9.599*** (2.713)	0.118	0.372 (3.261)	0.004	-10.607*** (2.911)	0.093
81-100	15.015*** (2.699)	0.150	0.099 (4.483)	0.001	-13.500*** (3.062)	0.096
Use of intranet (% of employees) ⁽⁴⁾ :						
1-20	-0.096 (1.062)	0.002	-0.026 (2.136)	0.000	0.907 (2.319)	0.013
21-40	1.603 (1.126)	0.036	4.040** (2.047)	0.074	-6.251*** (2.197)	0.100
41-60	1.593 (1.164)	0.038	3.291 (2.091)	0.064	-4.233** (2.196)	0.072
61-80	3.386** (1.456)	0.063	3.203 (2.307)	0.048	-6.727*** (2.438)	0.088
81-100	13.047*** (2.108)	0.233	1.539 (2.611)	0.023	-14.598*** (2.431)	0.186
<i>Workplace Organization:</i>						
Team-work ⁽⁵⁾	3.344*** (1.003)	0.0759	-0.801 (1.338)	0.015	-2.440* (1.376)	0.039
Job rotation ⁽⁵⁾	0.222 (1.685)	0.003	-2.838 (2.959)	0.027	3.962 (2.875)	0.032
Delegation of competences						
From managers to employees:						
Overall delegation of competences from managers to employees ⁽⁶⁾	-0.328 (0.784)	0.009	-0.962 (1.097)	0.022	0.691 (1.111)	0.012
Investment decisions are discussed in work-teams ⁽⁷⁾	1.932* (1.079)	0.041	-1.724 (1.441)	0.030	-0.247 (1.446)	0.004
Employees competence for the sequence of performing tasks ⁽⁸⁾	2.622** (1.108)	0.054	0.496 (1.577)	0.008	-2.441 (1.531)	0.036
Employees competence for the way of performing tasks ⁽⁸⁾	2.137** (1.050)	0.046	2.810** (1.419)	0.049	-4.878*** (1.458)	0.074

Decrease of number of managerial levels ⁽⁹⁾	-2.136 (1.943)	0.027	0.671 (2.676)	0.007	2.743 (2.360)	0.025
<i>Compensation, working conditions:</i>						
Team compensation ⁽¹⁰⁾	1.804** (0.841)	0.046	-1.010 (1.167)	0.021	-0.651 (1.176)	0.012
Part-time work ⁽¹¹⁾	-2.111** (0.877)	0.052	-1.283 (1.220)	0.027	3.692** (1.263)	0.065
Flexible working time ⁽¹¹⁾	1.860** (0.758)	0.051	-0.439 (1.077)	0.010	-1.992* (1.115)	0.039
<i>Firm size:</i>						
50-99 employees	-0.106 (0.987)	0.003	-1.719 (1.478)	0.034	3.047** (1.490)	0.052
100-199 employees	1.332 (1.032)	0.030	-5.231*** (1.479)	0.096	4.940*** (1.545)	0.079
200-499 employees	0.805 (1.279)	0.016	-3.245* (1.686)	0.052	4.009** (1.731)	0.056
500-999 employees	2.102 (2.119)	0.025	-3.996* (2.419)	0.039	2.934 (2.477)	0.024
> 999 employees	1.721 (2.328)	0.018	-4.849* (2.484)	0.042	1.781 (2.758)	0.013
N	1544		1544		1544	
DF	52		52		52	
SER	14.215		20.338		21.023	
F	18.6***		5.8***		14.1***	
R ² adj.	0.372		0.140		0.307	

Notes: (1): share of employees with *high* formal education (university, technical and business colleges); (2): share of employees with *middle* education (formal degree in vocational education); (3): share of employees with *low* formal education (vocational education without a formal degree; no vocational education); (4): 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*)); (5): 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)); (6): dummy variable (value 1 for firms reporting that in the period 1995-2000 (not further specified) competences were transferred from managers to employees); (7): 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)); (8): dummy variables (value 1 for firms reporting that at the workplace level employees have the competence to determine the *sequence of performing tasks* (the way tasks are performed) (values 4 and 5 on a five-point Likert scale)); (9): dummy variable (value 1 for firms reporting that the number of *managerial levels* decreased in the period 1995-2000); (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 yearly working time*) is ‚important‘ (values 4 and 5 on a five-point Likert scale)); estimations include also 2-digit industry controls (27 dummies); ***, **, * denote statistical significance at the 1%, 5% and 10% level respectively; the columns (1a), (2a) and (3a) contain the original coefficients, columns (1b), (2b) and (3b) contain the absolute values of the standardized coefficients; heteroscedasticity-robust standard errors (White procedure).

Table 6: Full Model: Determinants of the *Increase* of the Employment Shares of High-Educated, Middle-Educated and Low-Educated Employees 1997-2000 (Probit estimates)

Explanatory Variables	High-educated ⁽¹⁾		Middle-educated ⁽²⁾		Low-educated ⁽³⁾	
	(1a)	(1b)	(2)	(2a)	(3)	(3a)
Intercept	-1.291**		-0.543**		-1.756***	
	(0.231)		(0.245)		(0.311)	
<i>Technology:</i>						
Use of internet (% of employees) ⁽⁴⁾						
1-20	-0.041	0.020	-0.103	0.052	0.033	0.017
	(0.138)		(0.145)		(0.175)	
21-40	0.138	0.055	0.004	0.001	-0.026	0.011
	(0.151)		(0.162)		(0.198)	
41-60	-0.001	0.000	0.139	0.039	-0.055	0.015
	(0.179)		(0.194)		(0.255)	
61-80	0.034	0.007	0.199	0.044	-0.738*	0.164
	(0.205)		(0.225)		(0.392)	
81-100	-0.250	0.044	-0.144	0.026	-0.515	0.092
	(0.254)		(0.301)		(0.550)	
Use of intranet (% of employees) ⁽⁴⁾ :						
1-20	0.164	0.061	0.187	0.069	-0.062	0.023
	(0.142)		(0.149)		(0.167)	
21-40	0.160	0.064	0.157	0.064	-0.426**	0.173
	(0.137)		(0.144)		(0.172)	
41-60	0.216	0.092	0.022	0.009	-0.375**	0.161
	(0.133)		(0.141)		(0.165)	
61-80	0.461***	0.155	0.245	0.083	-0.076	0.026
	(0.150)		(0.161)		(0.190)	
81-100	0.426**	0.137	-0.179	0.058	-0.916***	0.299
	(0.168)		(0.191)		(0.296)	
<i>Workplace Organization:</i>						
Team-work ⁽⁵⁾	0.054	0.021	-0.094	0.038	-0.450***	0.184
	(0.087)		(0.099)		(0.144)	
Job rotation ⁽⁵⁾	0.131	0.027	0.029	0.006	-0.430	0.089
	(0.169)		(0.187)		(0.274)	
Delegation of competences						
From managers to employees:						
Overall delegation of competences from managers to employees ⁽⁶⁾	0.267***	0.133	0.093	0.046	0.130	0.065
	(0.074)		(0.081)		(0.104)	
Investment decisions are discussed in work-teams ⁽⁷⁾	0.186**	0.070	-0.041	0.015	0.202	0.076
	(0.091)		(0.104)		(0.128)	
Employees competence for the sequence of performing tasks ⁽⁸⁾	0.155	0.057	-0.012	0.005	0.274**	0.102
	(0.096)		(0.110)		(0.138)	
Employees competence for the way of performing tasks ⁽⁸⁾	0.039	0.015	0.026	0.010	-0.192	0.074
	(0.093)		(0.104)		(0.138)	

Decrease of number of managerial levels ⁽⁹⁾	0.443*** (0.143)	0.101	0.275* (0.160)	0.064	0.457** (0.189)	0.106
<i>Compensation, working conditions:</i>						
Team compensation ⁽¹⁰⁾	0.112 (0.077)	0.051	0.169** (0.084)	0.079	0.158 (0.106)	0.074
Part-time work ⁽¹¹⁾	0.042 (0.081)	0.019	0.080 (0.089)	0.036	0.204* (0.111)	0.092
Flexible working time ⁽¹¹⁾	-0.054 (0.073)	0.026	0.015 (0.081)	0.007	0.014 (0.102)	0.007
<i>Firm size:</i>						
50-99 employees	0.159 (0.097)	0.069	0.030 (0.104)	0.013	0.152 (0.130)	0.065
100-199 employees	0.384*** (0.102)	0.153	0.067 (0.111)	0.027	0.182 (0.140)	0.073
200-499 employees	0.422*** (0.114)	0.147	0.140 (0.126)	0.049	0.206 (0.158)	0.072
500-999 employees	0.535*** (0.165)	0.116	0.294 (0.188)	0.062	-0.230 (0.301)	0.049
> 999 employees	0.470*** (0.183)	0.093	0.048 (0.221)	0.009	-0.453 (0.386)	0.085
N	1544		1544		1544	
DF	52		52		52	
Likelihood ratio (χ^2)	200.0**		70.6**		123.7***	
R ² (rescaled R ²)	0.115 (0.163)		0.052 (0.075)		0.090 (0.169)	
% concordant	71.2		64.2		74.7	

Notes: (1): binary variable (value 1 for firms reporting an increase of the share of employees with *high* formal education (university, technical and business colleges) 1997-1999 (values 4 and 5 on a five-point Likert scale)); (2): binary variable (value 1 for firms reporting an increase of the share of employees with *middle* education (formal degree in vocational education) 1997-1999 (values 4 and 5 on a five-point Likert scale)); (3): binary variable (value 1 for firms reporting an increase of the share of employees with *low* formal education (vocational education without a formal degree; no vocational education) 1997-1999 (values 4 and 5 on a five-point Likert scale)); (4): 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)); (5): 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)); (6): dummy variable (value 1 for firms reporting that in the period 1995-2000 (not further specified) competences were transferred from managers to employees); (7): 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)); (8): dummy variables (value 1 for firms reporting that at the workplace level employees have the competence to determine the *sequence of performing tasks (the way tasks are performed)* (values 4 and 5 on a five-point Likert scale)); (9): dummy variable (value 1 for firms reporting that the number of *managerial levels* decreased in the period 1995-2000); (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 yearly working time)* is 'important' (values 4 and 5 on a five-point Likert scale)); estimations include also 2-digit industry controls (27 dummies); ***, **, *

* denote statistical significance at the 1%, 5% and 10% level respectively; the columns (1a), (2a) and (3a) contain the original coefficients, columns (1b), (2b) and (3b) contain the absolute values of the standardized coefficients.

Table 7: Determinants of the Employment Shares of High-Educated, Middle-Educated and Low-Educated Employees 1999 (OLS estimates of a version of the model with composite indices for technology and organization based on stardardized values)

Explanatory Variables	High-educated ⁽¹⁾		Middle-educated ⁽²⁾		Low-educated ⁽³⁾	
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
Intercept	11.193** (1.735)		43.262*** (2.836)		42.300*** (3.287)	
TECHNS ⁽⁴⁾	2.186*** (0.266)	0.207	0.387 (0.389)	0.030	-2.547*** (0.396)	0.172
ORGANS ⁽⁵⁾	0.321* (0.1449)	0.053	0.102 (0.239)	0.014	-0.315 (0.252)	0.037
TECHNS*ORGANS ⁽⁶⁾	0.540*** (0.106)	0.165	-0.188 (0.137)	0.047	-0.353*** (0.126)	0.077
<i>Compensation, working conditions:</i>						
Team compensation ⁽⁷⁾	2.668*** (0.866)	0.068	-1.601 (1.151)	0.033	-1.017 (1.182)	0.018
Part-time work ⁽⁸⁾	-2.221** (0.917)	0.055	-1.462 (1.215)	0.030	3.945*** (1.309)	0.070
Flexible working time ⁽⁸⁾	2.023*** (0.791)	0.055	-0.274 (1.075)	0.006	-2.335** (1.152)	0.045
<i>Firm size:</i>						
50-99 employees	-0.745 (1.031)	0.018	-2.021 (1.478)	0.040	4.019*** (1.509)	0.069
100-199 employees	-0.046 (1.071)	0.001	-5.674*** (1.457)	0.104	6.761*** (1.533)	0.108
200-499 employees	-0.507 (1.316)	0.010	-3.582** (1.663)	0.057	5.529*** (1.777)	0.077
500-999 employees	1.223 (2.258)	0.015	-4.572* (2.342)	0.045	4.119 (2.624)	0.035
> 999 employees	1.295 (2.326)	0.014	-5.025** (2.509)	0.044	2.126 (2.780)	0.016
N	1544		1544		1544	
DF	38		38		38	
SER	14.768		20.342		21.604	
F	20.3***		7.6***		15.9***	
R ² adj.	0.322		0.140		0.268	

Notes: (1): share of employees with *high* formal education (university, technical and business colleges); (2): share of employees with *middle* education (formal degree in vocational education); (3): share of employees with *low* formal education (vocational education without a formal degree; no vocational education); (4): sum of the values of the stardardized variables for user intensity of internet and intranet (two variables measured on a five-point Likert scale); (5): sum of the values of the

standardized variables for work place organization (seven dummy variables for: job rotation; team-work; decrease of the number of managerial levels in the period 1995-2000; overall transfer of (unspecified) competences from managers to employees in the period 1995-2000; employees have at the workplace level the competence to determine the *sequence of performing tasks* and the *way tasks are performed*, investment decisions are discussed in work-teams); (6) interaction term of ORGANS and TECHNS; (7): 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)); (8): dummy variable (value 1 for firms reporting that *part-time work (flexible yearly working time)* is ,important‘ (values 4 and 5 on a five-point Likert scale)); estimations include also 2-digit industry controls (27 dummies); ***, **, * denote statistical significance at the 1%, 5% and 10% level respectively; the columns (1a), (2a) and (3a) contain the original coefficients, columns (1b), (2b) and (3b) contain the absolute values of the standardized coefficients; heteroscedasticity-robust standard errors (White procedure).

Table 8: Determinants of the *Increase* of the Employment Shares of High-Educated, Middle-Educated and Low-Educated Employees 1997-2000 (Probit estimates of a version of the model with composite indices for technology and organization based on stardardized values)

Explanatory Variables	High-educated ⁽¹⁾		Middle-educated ⁽²⁾		Low-educated ⁽³⁾	
	(1a)	(1b)	(2)	(2a)	(3)	(3a)
Intercept	-0.882*** (0.182)		-0.407** (0.195)		-1.883*** (0.253)	
TECHNS ⁽⁴⁾	0.063*** (0.024)	0.107	0.041 (0.027)	0.068	-0.078** (0.031)	0.128
ORGANS ⁽⁵⁾	0.066*** (0.013)	0.192	0.021 (0.016)	0.053	0.009 (0.017)	0.027
TECHNS*ORGANS ⁽⁶⁾	-0.011 (0.007)	0.062	-0.013 (0.008)	0.073	-0.010 (0.010)	0.054
<i>Compensation, working conditions:</i>						
Team compensation ⁽⁷⁾	0.130* (0.075)	0.060	0.162** (0.082)	0.076	0.078 (0.101)	0.036
Part-time work ⁽⁸⁾	0.037 (0.081)	0.017	0.067 (0.089)	0.030	0.175* (0.106)	0.079
Flexible working time ⁽⁸⁾	-0.033 (0.072)	0.016	0.013 (0.080)	0.007	-0.018 (0.098)	0.009
<i>Firm size:</i>						
50-99 employees	0.163* (0.096)	0.070	0.034 (0.104)	0.015	0.188 (0.125)	0.081
100-199 employees	0.367*** (0.100)	0.147	0.032 (0.109)	0.013	0.203 (0.132)	0.082
200-499 employees	0.435*** (0.110)	0.151	0.120 (0.123)	0.042	0.288* (0.148)	0.100
500-999 employees	0.563*** (0.162)	0.122	0.236 (0.188)	0.050	-0.198 (0.283)	0.042
> 999 employees	0.519** (0.178)	0.102	-0.075 (0.223)	0.014	-0.467 (0.369)	0.088
N	1544		1544		1544	
DF	38		38		38	
Likelihood ratio (χ^2)	174.3***		56.2**		70.6***	
R ² (rescaled R ²)	0.101 (0.144)		0.043 (0.061)		0.052 (0.099)	
% concordant	69.8		62.8		69.1	

Notes: (1): binary variable (value 1 for firms reporting an increase of the share of employees with *high* formal education (university, technical and business colleges) 1997-1999 (values 4 and 5 on a five-point Likert scale)); (2): binary variable (value 1 for firms reporting an increase of the share of

employees with *middle* education (formal degree in vocational education) 1997-1999 (values 4 and 5 on a five-point Likert scale)); (3): binary variable (value 1 for firms reporting an increase of the share of employees with *low* formal education (vocational education without a formal degree; no vocational education) 1997-1999 (values 4 and 5 on a five-point Likert scale)); (4): sum of the values of the values of the stardardized variables for user intensity of internet and intranet (two variables measured on a five-point Likert scale); (5): sum of the values of the standardized variables for work place organization (seven dummy variables for: job rotation; team-work; decrease of the number of managerial levels in the period 1995-2000; overall transfer of (unspecified) competences from managers to employees in the period 1995-2000; employees have at the workplace level the competence to determine the *sequence of performing tasks* and the *way tasks are performed*, investment decisions are discussed in work-teams); (6) interaction term of ORGANS and TECHNS; (7): 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)); (8): dummy variable (value 1 for firms reporting that *part-time work (flexible yearly working time)* is ,important‘ (values 4 and 5 on a five-point Likert scale)); estimations include also 2-digit industry controls (27 dummies); ***, **, * denote statistical significance at the 1%, 5% and 10% level respectively; the columns (1a), (2a) and (3a) contain the original coefficients, columns (1b), (2b) and (3b) contain the absolute values of the standardized coefficients.

Table 9: Determinants of the Employment Share of High-Educated, Middle-Educated and Low-Educated Employees (2SLS estimates of the model version with composite indices for technology and organization; ORGANS is instrumented)

Explanatory variables	High-Educated ⁽¹⁾ 2SLS estimate (1)	Middle-Educated ⁽²⁾ 2SLS estimate (2)	Low-Educated ⁽³⁾ 2SLS estimate (3)	first stage estimate ORGANS (4)
Intercept	11.941*** (2.962)	42.700*** (3.174)	42.391 (3.102)	-0.705* (0.420)
TECHNS ⁽⁴⁾	2.023*** (0.362)	0.472 (0.388)	-2.546*** (0.379)	
ORGANS ⁽⁵⁾	5.455*** (1.549)	-3.040* (1.659)	-0.149 (1.622)	
TECHNS*ORGANS ⁽⁶⁾	0.596*** (0.103)	-0.157 (0.111)	-0.413*** (0.108)	
Team compensation ⁽⁷⁾	-2.022 (1.843)	1.193 (1.975)	-1.128 (1.930)	0.826*** (0.159)
Part-time work ⁽⁸⁾	-3.194** (1.305)	-0.788 (1.398)	3.886*** (1.367)	0.169 (0.171)
Flexible working time ⁽⁸⁾	-0.116 (1.302)	1.089 (1.395)	-2.478* (1.363)	0.399*** (0.152)
Innovative activities ⁽⁹⁾				0.713*** (0.176)
Export share ⁽¹⁰⁾				0.359 (0.282)
Foreign firm ⁽¹¹⁾				0.441** (0.209)
<i>Firm size:</i>				
50-99 employees	-1.847 (1.475)	-1.232 (1.580)	3.916** (1.545)	0.115 (0.195)
100-199 employees	-0.705 (1.554)	-5.292*** (1.665)	6.867*** (1.627)	0.030 (0.208)
200-499 employees	-3.391* (1.934)	-1.772 (2.073)	5.402*** (2.026)	0.401* (0.235)
500-999 employees	-4.168 (3.117)	-1.161 (3.340)	3.803 (3.264)	0.857** (0.360)
> 9999 employees	-1.908 (3.138)	-3.104 (3.362)	2.050 (3.287)	0.502 (0.404)
N	1535	1535	1535	1535
DF	38	38	38	38
SER	20.684	22.161	21.663	2.781
F	10.3***	6.5***	15.5***	5.06***
R ² adj.	0.188	0.119	0.264	0.092

Notes: (1): share of employees with *high* formal education (university, technical and business colleges); (2): share of employees with *middle* education (formal degree in vocational education); (3): share of employees with *low* formal education (vocational education without a formal degree; no vocational education); (4): sum of the values of the standardized variables for user intensity of internet and intranet (two variables measured on a five-point Likert scale); (5): sum of the values of the standardized variables for work place organization (seven dummy variables for: job rotation; team-work; decrease of the number of managerial levels in the period 1995-2000; overall transfer of (unspecified) competences from managers to employees in the period 1995-2000; employees have at the workplace level the competence to determine the *sequence of performing tasks* and the *way tasks are performed*, investment decisions are discussed in work-teams); (6) interaction term of ORGANS and TECHNS; (7): 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)); (8): dummy variable (value 1 for firms reporting that *part-time work (flexible yearly working time)* is ,important‘ (values 4 and 5 on a five-point Likert scale)); (9): dummy variable (value 1 for firms reporting the introduction of product and / or process innovations in the period 1998-2000); (10): exports as a share of sales; (11): dummy variable (value 1 for firms reporting that they belong to a foreign enterprise); estimations include also 2-digit industry controls (27 dummies); ***, **, * denote statistical significance at the 1%, 5% and 10% level respectively.

Table 10: Survey of Recent Empirical Literature

Study	Dependent Variable	ICT; TECH	ORG	Complementarity ICT;TECH/ORG
USA:				
<i>Capelli/Carter (2000):</i>				
- longitudinal	<i>average wages of:</i>			
	managers/	positive	pos./neg.	n.c.
	professionals			
	supervisors	positive	pos./neg. ⁽¹⁾	n.c.
	technical workers	positive	n.s./neg. ⁽¹⁾	n.c.
	office workers	positive	pos./neg. ⁽¹⁾	n.c.
	production workers	positive	pos./neg. ⁽¹⁾	n.c.
<i>Bresnahan et al. (2002):</i>				
- cross-section	<i>human capital investment</i>	positive	positive	n.c.
UK:				
<i>Caroli/Van Reenen (2001):</i>				
- longitudinal	<i>changes in the wage bill shares of:</i>			
	unskilled manuals	n.s.	negative	not robust
	semi-skilled manuals	n.s.	n.s.	not robust
	skilled manuals	negative	positive	not robust
	clerical workers	ns	n.s.	not robust
	supervisors/foremen	positive	n.s.	not robust
	managers/technical staff	positive	n.s.	not robust
France:				
<i>Caroli/Van Reenen (2001):</i>				
- longitudinal	<i>changes in the wage bill shares of:</i>			
	unskilled manuals	n.s.	negative	n.s.
	skilled manuals	n.s.	positive	n.s.
	clerical workers	n.s.	n.s.	n.s.
	middle managers/ technicians	n.s.	n.s.	positive
	senior managers	n.s.	n.s.	n.s.
<i>Caroli et al. (2001):</i>				
- longitudinal	<i>probability of employment increase for:</i>			
	managers	n.a.	n.s.	n.c.
	intermediate workers	n.a.	negative	n.c.
	operatives	n.a.	negative	n.c.
<i>Greenan (2003):</i>				
- cross-section	<i>employment shares of:</i>			

	executives	n.s.	negative	n.c.
	middle management	negative	n.s.	n.c.
	clerks	n.s.	n.s.	n.c.
	skilled blue workers	n.s.	negative	n.c.
	unskilled blue workers	pos./neg. ⁽²⁾	positive	n.c.
- cross-section	<i>growth rate of employment shares of:</i>			
	executives	n.s.	positive	n.c.
	middle management	n.s.	n.s.	n.c.
	clerks	negative	negative	n.c.
	skilled blue workers	n.s.	negative	n.c.
	unskilled blue workers	n.s.	n.s.	n.c.
Germany:				
<i>Gerlach/Jirjahn (1998):</i>				
- longitudinal	<i>employment share of:</i>			
	workers w.vocational degree	positive	n.s.	n.c.
	foremen/technicians	n.s.	n.s.	n.c.
	university graduates	positive	positive	n.c.
<i>Bauer/Bender (2001):</i>				
- longitudinal	<i>employment share of:</i>			
	blue-collar workers:			
	unskilled	n.s.	n.s.	n.s.
	skilled	n.s.	n.s.	n.s.
	high-skilled	n.s.	n.s.	n.s.
	white-collar workers:			
	unskilled	n.s.	negative	negative
	skilled	n.s.	n.s.	n.s.
	high-skilled	n.s.	n.s.	n.s.
	<i>average wages of:</i>			
	blue-collar workers:			
	unskilled	n.s.	negative	n.s.
	skilled	n.s.	negative	n.s.
	high-skilled	n.s.	n.s.	n.s.
	white-collar workers:			
	unskilled	n.s.	negative	n.s.
	skilled	negative	negative	n.s.
	high-skilled	n.s.	n.s.	n.s.
<i>Falk (2002):</i>				
- cross-section	<i>probability of employment increase for:</i>			
	university graduates	positive	positive	n.c.
	masters/technicians	positive	positive	n.c.
	vocational degree	n.s.	positive	n.c.
	unskilled workers	n.s.	n.s.	n.c.
<i>Hujer et al. (2002):</i>				
- longitudinal	<i>employment share of:</i>			
	high-skilled	positive	n.s.	n.c.
	low-skilled	negative	n.s.	n.c.

Italy:

Piva et al. (2003):

- cross-section

*log of difference of
the number of:*

white-collar workers	n.s.	n.s.	positive
blue-collar workers	n.s.	negative	negative

Notes: (1): positive: team-work, reduction of management levels, regular meetings; negative: job rotation; (2): partly positive, partly negative coefficients; ICT: information and communication technologies; ORG: workplace organization; „positive“ („negative“): statistically significant (at the test level of 10%) positive (negative) coefficient of the variables(s) for ICT, ORG and the interaction term of these two variables respectively; n.s.: statistically not significant (at the test level of 10%); n.c.: not considered; n.a.: not available (for such cases in which the corresponding variables are included in the models, but the results are not explicitly presented).

Table A.1: Composition of the dataset

	N	Percent
<i>Industry:</i>		
Food, beverage	69	4.5
Textiles	27	1.7
Clothing, leather	15	1.0
Wood processing	19	1.2
Paper	27	1.7
Printing	57	3.7
Chemicals	56	3.6
Plastics, rubber	31	2.0
Glass, stone, clay	31	2.0
Metal	17	1.1
Metal working	120	7.8
Machinery	137	8.9
Electrical machinery	37	2.4
Electronics, instruments	83	5.4
Watches	27	1.7
Vehicles	17	1.1
Other manufacturing	33	2.1
Energy, water	27	1.7
Construction	169	10.9
Wholesale trade	162	10.5
Retail trade	94	6.1
Hotels, catering	37	2.4
Transport, telecommunication	70	4.5
Banks, insurance	60	3.9
Real estate, leasing	4	0.3
Computer services	22	1.4
Business services	88	5.7
Personal services	8	0.5
<i>Firm Size:</i>		
20-49 employees	495	32.1
50-99 employees	375	24.3
100-199 employees	311	20.1
200-499 employees	221	14.3
500-999 employees	77	5.0
> 1000 employees	65	4.2
Total	1544	100