Productivity Effects of Organizational Change: Microeconometric Evidence [§]

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June 2001

Abstract: This paper analyzes the relationship between investment in information and communication technologies, workplace reorganization change and labor productivity. Firms are assumed to reorganize workplaces if the productivity gains arising from workplace reorganization exceed the associated reorganization costs. Two different types of organizational change are considered: enhancement of group work and flattening of hierarchies. Empirical evidence is provided for a sample of 411 firms from the German business–related services sector.
Our main result from a simultaneous model for labor productivity and firms' decision to reorganize workplaces indicate that (i) the output elasticities of information and communication technologies (ICT), non–ICT capital and labor do not significantly differ between the productivity regimes with and without workplace reorganization and (ii) the entire productivity distribution — where changes in the productivity shift parameters are taken into account — shifts out to the right, indicating that workplace reorganization induces an increase in labor productivity. Finally, we do not find significant differences in the output elasticities ICT and non–ICT capital.

JEL classification: $C25, D24$

Keywords: workplace reorganization, ICT–investment, labor productivity, endogenous switching regression model, kernel density estimation

[§]Ulrich Kaiser gratefully acknowledges financial support by the German Science Foundation (Deutsche Forschungsgemeinschaft, DFG) for partially funding this research within the 'Industrial Economics and Input Markets' program under grants PF331/1–1,1–2,1–3 and PO 375/3–1,3–2,3–3.

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Non–technical summary

Do information and communication technologies (ICT) affect labor productivity? Economists tend to answer this simple question with their usual statement: it depends. It in fact depends upon the level of investigation. Numerous studies on the sectoral and on an economy–wide level have demonstrated that even if positive productivity effects exist, they may be small in magnitude. Studies at the firm level, however, usually find highly significant and positive effects of ICT. But is it really likely that ICT *directly* induces a shift in labor productivity? Management scientists and economists have recently argued that it is the reorganization of workplaces which actually causes productivity gains at the firms level. The present study follows this view and analyzes the effects of workplace reorganization on labor productivity on the basis of a sample of 411 German firms from the dynamically growing business–related services sector. Two types of organizational change are considered: (i) enhancement of group work and (ii) flattening of hierarchies.

A simultaneous equations model is developed which takes into account the potential simultaneity of labor productivity and workplace reorganization. The estimation results indicate that (i) the output elasticities of information and communication technologies (ICT), capital other than ICT and labor do not significantly differ between the productivity regimes with and without workplace reorganization and that (ii) the entire productivity distribution — where it is also accounted for changes in the productivity shift parameters — shifts out to the right, indicating that workplace reorganization induces an increase in labor productivity. Finally, we do not find significant differences in the output elasticities between ICT and non–ICT capital.

1 Introduction

The fast technological development of information and communication technologies (ICT) as well as the declining prices for the use of ICT have enhanced considerably the diffusion of ICT during the last few years. As a consequence, the impact of ICT on productivity has become a controversially discussed topic in management science and economics. At the firm–level, several studies find empirical evidence for positive productivity effects of ICT using alternative ICT-measures: Brynjolfsson and Hitt (1996) analyze productivity effects of ICT–capital and ICT–labor using data from over 300 large firms of the manufacturing and the service sector in the U.S. for the period 1988 to 1992. Similar results are found by Lichtenberg (1995). Greenan and Mairesse (1996) use French matched employer–employee data related to seven industries and three years and find positive and significant impacts of computer use on labor productivity. Contrary results are provided by Licht and Moch (1999), whose estimates for the productivity effects of ICT–investment for the German service sector are insignificant. They, however, show that the productivity effects of ICT vary markedly with different types of ICT.

Some recent papers suggest that ICT-investment has to go hand in hand with appropriate organizational changes in order to result in positive productivity effects — a hypothesis that could contribute to the explanation of the so–called "productivity paradox" (see for instance Triplett, 1999, for an extensive discussion).

Until recently there have been mainly two strands of literature dealing with the relations between ICT-investment, organizational change and productivity. One strand concentrates on the impact of ICT-investment on organizational changes. For instance, Leavitt and Whisler, as cited by Crowston and Malone (1988, p. 1051), already predicted in 1958 that "the use of information and communication technology would lead to the demise of middle management" and that the number of hierarchy levels in organizations will decrease if, for instance, computers are increasingly often used to perform the functions of the middle management. During the 70s and 80s, there was a broad discussion about the effects of ICT on workplace organization, with ICT being defined as something in between a new payroll system and a new personal computer. Due to binding data restrictions, few empirical analyzes of the relationship between workplace organization and ICT exist for that time period.

The other strand of the literature mainly deals with the impact of workplace organization or human resource management on productivity (Huselid, 1995; Ichniowski et al., 1997; Milgrom and Roberts, 1990).

Studies on the effects of ICT *and* organizational change on firms' productivity emerged only recently. It seems plausible that the implementation of a new information and communication system alone is not sufficient to cause positive productivity effects. The implementation of a new software system such as SAP,

for example, often demands a restructuring of the company in order to efficiently use this new system. Thus, it appears likely that workplace organization has to be changed accordingly in order to make workflow more efficient or, to put it differently, that ICT is enabling organizational change, as pointed out recently by Brynjolfsson and Hitt (2000). Related evidence is provided by Black and Lynch (1997), who analyze the productivity effects of several workplace practices, ICT and human capital using cross section and panel estimations on a data set of about 600 firms of the U.S. manufacturing industry. Their results indicate that workplace reorganization has positive and significant effects on labor productivity. Bresnahan et al. (2000) also find empirical evidence that ICT, workplace reorganization and new products and services are complementary factors in the determination of the demand for high-skilled labor and to increased productivity. While existing studies (e.g. Black and Lynch, 1997; Bresnahan et al., 2000; Brynjolfsson and Hitt, 2000) assume workplace reorganization to be exogenous to labor productivity, this paper allows for a simultaneity between productivity and firms' decisions to reorganize workplaces.

A firm's decision to reorganize workplaces is assumed to depend on the differences in productivity with and without workplace reorganization. An endogenous regime switching regression model is developed and estimated on a sample of 411 firms from the German business–related services sector.

Our estimates show that workplace reorganization in fact is endogenous to labor productivity. Organizational changes in the form of enhanced group work and flattening of hierarchies cause the labor productivity distributions to shift to the right, implying that both forms of workplace reorganization lead to gains in labor productivity. Thus, as indicated by earlier studies, it seems to be advisable to enlarge the discussion of productivity effects of ICT by taking into account organizational change.

Further estimation results are that (i) the output elasticities of information and communication technologies (ICT), capital other than ICT and labor do not significantly differ between the productivity regimes with and without workplace reorganization and that (ii) we do not find significant differences in the output elasticities between ICT and non–ICT capital.

Interestingly, if workplace reorganization is considered as a simple productivity shift variable as it is usually done in existing studies (e.g. Black and Lynch, 1997; Breshnahan et al., 2000; Brynjolfsson and Hitt, 2000), we do not find significant effects of workplace reorganization on productivity. When the same set of explanatory variables for the labor productivity regressions as in Section 4 are run and if a dummy variable for the different types of workplace reorganization is included instead of estimating a switching regression model, we do not find significant effects of workplace organization on labor productivity.[1] This indi-

[1]The point estimate (standard errors in parenthesis) corresponding to the enhancement of group work is 0.0862 (0.0818) and for the flattening of hierarchies it is 0.0364 (0.0910). and for

cates that workplace reorganization induces a change in the entire set of output elasticity coefficients and productivity shift variables such as sector affiliation and regional affiliation dummy variables so that inserting a dummy variable for organizational change in a productivity equation may not fully reveal the effects of organizational change on productivity.

2 The model

We assume that firm i produces according to a Cobb–Douglas production technology. Output y_i is a function of labor input, L_i, capital, K_i, and ICT–capital, ICT_i, and a set of output shift variables which are summarized in vector $\boldsymbol{A_i}$:

$$y_i \;=\; \boldsymbol{A_i}\; L_i^{\alpha}\; ICT_i^{\beta}\; K_i^{\gamma}. \tag{1}$$

The exponents α and β denote the elasticities of output with respect to labor and ICT–capital respectively. Taking logs and adding an i.i.d. normally distributed error term, denoted by u_i, leads to

$$ln(y_i) \;=\; ln(\boldsymbol{A_i}) \;+\; \alpha\; ln(L_i) \;+\; \beta\; ln(ICT_i) \;+\; \gamma\; ln(K_i) \;+\; u_i. \tag{2}$$

Labor productivity, i.e. output per worker, is then given by:

$$ln\Big(\frac{y_i}{L_i}\Big) = ln(\boldsymbol{A_i}) + (\alpha-1)ln(L_i) + \beta ln(ICT_i) + \gamma ln(K_i) + u_i = \boldsymbol{X_i\delta} \;+\; u_i. \tag{3}$$

If a firm changes its organizational structure, its labor productivity is

$$\begin{aligned} ln\Big(\tfrac{y_i}{L_i}\Big)_{oc} &= ln(\boldsymbol{A_{i}}_{oc}) + (\alpha_{oc}-1)ln(L_i) + \beta_{oc} ln(ICT_i) + \gamma_{oc} ln(K_i) + u_{ioc} \\ &= \boldsymbol{X_i\delta_{oc}} \;+\; u_{ioc}. \end{aligned} \tag{4}$$

For firms not conducting an organizational change, labor productivity is

$$\begin{aligned} ln\Big(\tfrac{y_i}{L_i}\Big)_{noc} &= ln(\boldsymbol{A_{i}}_{noc}) + (\alpha_{noc}-1)ln(L_i) + \beta_{noc} ln(ICT_i) + \gamma_{noc} ln(K_i) + u_{inoc} \\ &= \boldsymbol{X_i\delta_{noc}} \;+\; u_{inoc}, \end{aligned} \tag{5}$$

where the subscripts *oc* and *noc* denote the two productivity regimes with and without organizational change respectively. Firms decide to reorganize workplaces if the productivity gain from workplace reorganization is larger than the costs per worker involved with an organizational change, C_i. Thus, the latent variable

$$I_i^* = a\;\left(ln(\frac{y_i}{L_i})_{oc} - ln(\frac{y_i}{L_i})_{noc}\right) \;-\; C_i \;+\; v_i \tag{6}$$

the installation of cost and profit centers it is 0.0457 (0.1032).

represents the difference between the productivity gains and the costs arising from an organizational change, where v_i is an i.i.d. normally distributed error term.
The selection mechanism for observing a workplace reorganization is

$$ORG_i \;=\; \begin{cases} 1 & \text{if } I^* > \; 0 \\ 0 & \text{otherwise.} \end{cases} \tag{7}$$

Substituting equations (4) and (5) into equation (6) leads to

$$I_i^* \;=\; a\;\boldsymbol{X_i}\;(\boldsymbol{\delta_{oc}} \;-\; \boldsymbol{\delta_{noc}}) \;-\; C_i \;+\; \epsilon_i \;=\; \boldsymbol{Z_i\Pi} \;+\; \epsilon_i, \tag{8}$$

where $\epsilon_i \;=\; a(u_{ioc} \;-\; u_{inoc}) \;+\; v_i$ follows a normal distribution with $N(0, \sigma^2_{ORG})$. The contribution of the ith observation to the likelihood function associated with such a system of equations is

$$\begin{array}{ll} P[I_i^* \;>\; 0]\;\phi\Big(ln(y_i/L_i)_{oc} \mid ORG = 1\Big) & \text{if} \quad ORG = 1 \\ P[I_i^* \;\leq\; 0]\;\phi\Big(ln(y_i/L_i)_{noc} \mid ORG = 0\Big) & \text{if} \quad ORG = 0, \end{array} \tag{9}$$

where ϕ denotes the density of the standard normal distribution function.
The distribution of I_i^* conditional on $ln(\frac{y_i}{L_i})_{oc}$ is:

$$ORG_{|ln(\frac{y_i}{L_i})_{oc}} \sim \; N\Big(\boldsymbol{Z_i\Pi} + \frac{\sigma_{ORG,ln(\frac{y_i}{L_i})_{oc}}}{\sigma^2_{ln(\frac{y_i}{L_i})_{oc}}}(ln(\tfrac{y_i}{L_i})_{oc} - \boldsymbol{X_i\delta_{oc}}); \sigma^2_{ORG}(1 - \rho^2_{ORG,ln(\frac{y_i}{L_i})_{oc}})\Big) \tag{10}$$

and likewise:

$$ORG_{|ln(\frac{y_i}{L_i})_{noc}} \sim N\Big(- \boldsymbol{Z_i\Pi} - \frac{\sigma_{ORG,ln(\frac{y_i}{L_i})_{noc}}}{\sigma^2_{ln(\frac{y_i}{L_i})_{noc}}}(ln(\tfrac{y_i}{L_i})_{noc} - \boldsymbol{X_i\delta_{noc}}); \sigma^2_{ORG}(1 - \rho^2_{ORG,ln(\frac{y_i}{L_i})_{noc}})\Big). \tag{11}$$

Denoting $\rho_{ORG,ln(\frac{y_i}{L_i})_l}$, the correlation between u_{il} and v_i, by ρ_l for $l = oc, noc$ and restricting $\sigma_{ORG} = 1$ for identification, the log–likelihood function associated with observation i is[2]

$$\begin{array}{c} ln\Phi\left(\frac{\boldsymbol{Z_i\Pi} + (ln(\frac{y_i}{L_i})_{oc} - \boldsymbol{X_i\delta_{oc}})\rho_{oc}/\sigma_{\frac{y_i}{L_i}oc}}{\sqrt{1-\rho^2_{oc}}}\right) - \frac{1}{2}\Big(\frac{ln(\frac{y_i}{L_i})_{oc} - \boldsymbol{X_i\delta_{oc}}}{\sigma_{ln(\frac{y_i}{L_i})_{oc}}}\Big)^2 - ln(\sqrt{2\Pi}\sigma_{ln(\frac{y_i}{L_i})_{oc}}) \text{ if } ORG = 1 \\ \text{and} \\ ln\Phi\left(\frac{-\boldsymbol{Z_i\Pi} + (ln(\frac{y_i}{L_i})_{noc}) - \boldsymbol{X_i\delta_{noc}})\rho_{noc}/\sigma_{\frac{y_i}{L_i}noc}}{\sqrt{1-\rho^2_{noc}}}\right) - \frac{1}{2}\Big(\frac{ln(\frac{y_i}{L_i})_{noc} - \boldsymbol{X_i\delta_{noc}}}{\sigma_{ln(\frac{y_i}{L_i})_{noc}}}\Big)^2 - ln(\sqrt{2\Pi}\sigma_{ln(\frac{y_i}{L_i})_{noc}}) \text{ if } ORG = 0. \end{array} \tag{12}$$

[2]The GAUSS code for the Maximum–likelihood function can be downloaded from Ulrich Kaiser's ZEW–website.

3 The Data

The strong economic growth of the service sector and especially that of business–related services has led to a heightened attention as far as the public, the media and policy are concerned.[3] In official statistics, however, business–related services play a rather subordinate role. To compensate for the lack of up–to–date data for business-related services, the Centre for European Economic Research (ZEW) has been carrying out the 'Service Sector Business Survey' (SSBS), a quarterly business survey in this sector in cooperation with Germany's largest credit rating agency Creditreform since June 1994. The ZEW sends out a single–sided questionnaire every three months to about 3500 firms belonging to the business-related services sector. The survey is constructed as a panel. It is a stratified random sample, stratified with respect to ten sectors, regional affiliation (East/West Germany) and five size classes (two for East, three for West Germany). Details on the survey design are presented in Kaiser et al. (2000). The response rate of the survey amounts to about 30 per cent per wave. The questionnaire is divided into two parts. In the first part, firms assess their current business development by answering questions concerning past development of sales, profits, demand, prices and employment on a three–point ordinal scale. The second part of the survey is concerned with present–day economic issues and changes quarterly with selected questions being repeated annually. This paper uses data taken from the 26th wave (third quarter of 2000) which contains information on workplace reorganization; the 26th wave currently is the only wave of the SSBS which contains information on workplace reorganization so that panel data estimations can presently not be provided. In particular, the questionnaire asks: "Did one of the following changes or reforms take place within your firm during the past three years?" The list of possible answers includes (i) enhancement of group work and (ii) flattening of hierarchies. We supplement the information contained in the 26th wave of the SSBS by data on ICT–investment, non–ICT investment, and total employment which is taken from the 24th wave (first quarter of 2000) of the SSBS. Since 408 firms which took part in the 26th wave of the SSBS but which did not respond to the 24th wave, these firms are lost for the estimations. A check if there are systematic differences in the anatomy of firms which have to be left out due to non–response indicated that these firms were merely missing at random.
Our analysis starts with some descriptive evidence on ICT–investment, non–ICT investment, firm size and workplace reorganization. Table 1 displays the share of

[3]Following Miles (1997), we define business-related services by enumeration of the following sectors (NACE Rev. 1 code in parenthesis): Computer services (72100, 72201–02, 72301–04, 72601–02, 72400), Legal and book–keeping activities (74123, 74127, 74121–22), Business management (74131–32, 74141–42), Architectural activities (74201–04), Technical testing and planning (74205–09, 74301–04), Advertising (74844, 74401-02), Vehicle renting (71100, 71210), Machine renting (45500, 71320, 71330), Cargo handling and storing (63121, 63403, 63401) and Waste and refuse disposal (90001–90007).

firms which conducted one of the two types of workplace reorganization. Group work enhancement is the more important type of workplace reorganization with a share of 37.6 of the firms in the sample, compared to a share of 28.2 per cent for the flattening of hierarchies. The declining order of importance replicates the degree of radicalness of the three two forms of workplace reorganization: while group work is relatively simple to establish, flattening of hierarchies requires a substantial change in human resource management since some of the employees will loose their ranks and titles.

Table 1: Percentage share of firms with workplace reorganization

Type of workplace reorganization:	Firm share (in %):	# of firms
Enhancement of group work	37.6	164
Flattening of hierarchies	28.2	117

Table 2 displays the quantiles, means and standard deviations of the most important variables used in the estimation of labor productivity: ICT–investment (in 1,000 DM), non–ICT capital investment (in 1,000 DM), output (proxied by annual sales in 1,000 DM), total employment and productivity (output per worker). It is shown that the firms in our sample are quite small compared to the mean and median employment in German manufacturing industries (Janz and Licht, 1999). The largest firm in the sample has 1,300 employees, the smallest has one employee. Interestingly, all firms have positive ICT–investment. This again differs from figures known for manufacturing industries, where ICT–investment is less widespread. On the average across firms, a worker produces 305,600 DM output (i.e. sales) per year with a median of 189,700 DM. Both means and medians of non–ICT investment are larger than those related to ICT investment. This, however, differs significantly across sectors. ICT–investment dominates non–ICT investment in computer services, legal and book–keeping activities, business management, architectural activities, technical testing and planning as well as advertising whereas non–ICT investment is relatively more important in vehicle and machine renting, cargo handling and storing as well as waste and refuse disposal.

4 Empirical results

The implementation of our empirical model is straightforward. Labor productivity is calculated as the ratio of total sales over the total number of employees. Non–ICT capital, K, is measured as investment in physical capital, ICT–capital

Table 2: Descriptive statistics

	Quantile				
	10 per cent	50 per cent	90 per cent	Mean	Std. err.
ICT–investment*	10	50	500	348.7	1663.8
Non ICT–capital investment*	10	150	2000	1151.6	5202.1
# of employees	5	20	122	54.9	112.6
Output*	1000	5000	23523	40000.0	102778.7
Productivity$^\circ$	20	78	580	687.1	273.1

* in 1,000 DM; $^\circ$ output per worker (total sales per year in 1,000 DM).

is proxied by ICT–investment. Proxying ICT–capital by ICT–investment does not appear as a severe shortcoming since ICT depreciates extremely quickly (Dewan and Min, 1997). With regard to the empirical proxy for non–ICT capital, it is important to note that a capital stock could potentially be calculated using information from past SSBS–waves. The SSBS, however, is a very volatile panel data set. Firms usually take part on an irregular basis so that a calculation of capital stock implies to work, due to unit–nonresponse, with a sample of between ten and twenty firms only.

Productivity differences, as represented by the term $\boldsymbol{A_i}$, in equations (1) to (5) are considered by the inclusion of a set of nine sector dummy variables and a dummy variable which is coded one if the respective firm is from East Germany and zero otherwise.

Workplace reorganization costs C_i cannot be directly observed. We therefore assume that these costs are (i) lower for exporting firms since these firms are used to adjust quickly to changes in the international market environment anyway, (ii) lower for firms facing foreign competition on the domestic market since increased competitive pressure induces firms to optimize their work flow and (iii) higher for firms which report that they have encountered difficulties in finding qualified applicants for open apprenticeship training positions.

Lagged business cycle effects are also likely to affect the decision to reorganize workplaces. We control for business cycle effects by using information from the first part of the SSBS–questionnaire. We aggregate firms' assessment of their sales development by calculating sales balance, i.e. the share of firms with positive sales development minus the share of firms with negative sales development in the respective SBSS–wave. We account for sector–specific, region–specific and firm size–specific differences by calculating the sales balances individually for each of the the business–related sectors and for East and West Germany; we then merge the balances to the respective firm types. We test for the optimal lag length using Likelihood Ratio tests. It turns out that sales balances of lag length two and three have most explanatory power in the decision to introduce

group work and that the sales balances do not significantly influence the decision to flatten hierarchies. The signs of the sales balances is not determined a priori since a negative sales development may cause firms to plan a restructuring but also restricts financial flexibility resources. In econometric terms, the dummy variables for exporting firms, for firms faced by foreign competitors and for firms with difficulties to recruit qualified apprenticeships are the identifying restrictions of equation (8).

Table 3 displays estimation results for the labor productivity equations and the two types of workplace reorganization. In addition, it presents the results of test for identity of the coefficients in the two different regimes, e.g. we test if the coefficients of $ln(L)$ are the same in the regime with organizational change as in the regime without organizational change. Estimation results for the separation equations are displayed in Table 4.

Results common to all estimations

Productivity estimations

Positive and highly significant effects of ICT–investment, non–ICT investment and labor on labor productivity are found in all productivity estimations, as shown in Table 3.[4] The point estimates corresponding to ICT–investment are larger in the regimes without workplace organization for both forms of organizational change; these differences are, however, insignificant. By contrast, the point estimates of non ICT–investment and of labor input are larger in the regime with workplace reorganization for both forms of workplace reorganization. Again, significant differences in the parameter estimates are not found. Even though the point estimates of the constant term, the dummy variable for East German firms and of the sector dummy variables tend to differ in absolute magnitude between the two forms regimes with and without workplace reorganization, identity of these parameters across the two workplace reorganization regimes cannot be rejected at the usual significance levels. Indeed, identity of the entire parameter vectors of the two regimes cannot be rejected at the usual significance levels as well. This is likely to be due to the fact that the productivity estimations for the regimes with organizational change are less precisely estimated than those related to the regimes with organizational change. This in turn is caused by a much lower number of firms which realize workplace reorganizations.

The parameter ρ_1 (ρ_2) measures the correlation between the error terms u_{ioc} (u_{inoc}) of the two labor productivity equations and the error term ϵ_i of the separation equation (8). If ρ_1 and ρ_2 are zero, the model reduces to an exogenous switching regression model (Maddala, 1983, pp. 283–84). The correlation coefficients are jointly significant in all of the equations indicating that treating work-

[4]Note that for labor input, the estimated coefficients displayed in Table 3 correspond to $\alpha - 1$ (compare equation (3)).

Table 3: Switching regression estimation results: level equations

	Group work reinforcement		**Flattening of hierarchies**	
	Coeff.	Std. err.	Coeff.	Std. err.
	Estimation results for regime w/ org. change			
$ln(ICT)$	0.1515***	0.0657	0.1566**	0.0767
$ln(K)$	0.1909***	0.0537	0.17***	0.0579
$ln(L)$	-0.348***	0.0874	-0.3227***	0.1256
East Germany	-0.0042	0.1563	-0.1202	0.1703
Constant	4.9325***	0.4893	4.8317***	0.8071
ρ_1	-0.1276	0.4228	0.125	0.474
σ_1	0.7618***	0.0519	0.7526***	0.0699
	Estimation results for regime w/o org. change			
$ln(ICT)$	0.1788***	0.0613	0.1965***	0.0619
$ln(K)$	0.1287***	0.0511	0.1338***	0.0558
$ln(L)$	-0.4273***	0.0683	-0.4638***	0.0603
East Germany	-0.1641*	0.1214	0.4323	0.1689
Constant	5.7326***	0.3745	-1.5688***	0.5215
ρ_2	-0.684***	0.1293	-0.6661***	0.1449
σ_2	0.8403***	0.082	0.83***	0.0754
	Wald tests for identity of the coefficients			
	Test stat.	p–value	Test stat.	p–value
$ln(ICT)$	0.0906	0.7635	0.1610	0.6883
$ln(K)$	0.6989	0.4031	0.1931	0.6603
$ln(L)$	0.5223	0.4699	0.9912	0.3194
Set of input factors	2.5543	0.4656	1.9054	0.5923
East Germany	0.6555	0.4181	0.0543	0.8157
Sector dummies	13.0798	0.1590	10.1340	0.3397
Constant	1.7001	0.1923	0.9870	0.3205
Entire specification	18.816	0.172	18.397	0.1893
	Wald tests for joint significance			
	χ^2	p–value	χ^2	p–value
	Regime with organizational change			
Factor inputs	25.2461	0.0000	17.5022	0.0006
Sector dummies	9.8068	0.3664	18.9125	0.0259
Entire specification	56.1704	0.0000	55.4586	0.0000
	Regime without organizational change			
Factor inputs	40.2062	0.0000	61.0335	0.0000
Sector dummies	30.4895	0.0004	18.9853	0.0253
Entire specification	95.1688	0.0000	100.7659	0.0000

Table 3 displays estimation results for the level equations of the endogenous switching regression model. A total of 411 observations was involved in the estimations. The asterisks ***, ** and * denote significance at the one, five and ten per cent significance level respectively.

place reorganization as truly exogenous for labor productivity is inappropriate. While the correlations between the selection equations and the level equations without workplace reorganization are insignificant, highly significant correlations exist for the selection equations and the productivity equations without workplace reorganization. This implies that an unanticipated productivity shock leads to a decrease in firms' propensity to reorganize workplaces.

Separation equation

Results common to the two reduced form separation equations, as displayed in Table 4, are that the identifying restrictions are jointly highly significant. The individual coefficients also carry the expected signs: exporting firms and firms facing foreign competition tend to significantly more often reorganize workplaces than non–exporters and firms without foreign competitors in the home market. Sector affiliation does not play a significant role in the decision to reorganize workplaces.

Results specific to the reinforcement of group work

Productivity estimations

The effect of workplace reorganization on the partial ICT–productivity is quite small, the partial ICT–productivity is slightly larger in the regime with enhancement of group work. By contrast, the numerical differences between the regimes with and without reinforcement of group work are markedly larger with respect to the output elasticities of non–ICT investment and labor input. As already mentioned above, these differences are, however, statistically insignificant.

In addition to Table 3 and 4, the results of Wald tests for identity of the partial output elasticities of ICT and non–ICT investment for the four productivity estimations are displayed in Table 5. Identity of the coefficients α and β cannot be rejected at the usual significance levels.

Figures 1 and 2 visualize the productivity differences between firms with workplace reorganization compared to those without workplace reorganization. Instead of just considering the point estimates related to the input factors, these figures visualize the joint productivity effects of workplace organization arising from changes in the output elasticities of the input factors and from the changes in the productivity shift parameters. Although statistically significant differences between the parameter estimates of the two regimes are not found, the estimation results nevertheless indicate that there are quite substantial differences in the parameter vector related to the set of firms with workplace reorganization and without workplace reorganization. These effects are visualized in Figures 1 and 2 for group work and in Figures 3 and 4 for the flattening of hierarchies.

The idea behind both figures is to consider the same firms — those with workplace reorganization (e.g. Figure 1) and those without workplace reorganization (e.g. Figure 2) — under the two different workplace reorganization regimes. The triangled curve ('parameter vector w/ group work reinforcement') represents Kernel

Table 4: Switching regression estimation results: selection equations

	Group work reinforcement		**Flattening of hierarchies**	
	Coeff.	Std. err.	Coeff.	Std. err.
$ln(ICT)$	0.0383	0.0632	0.0301	0.0654
$ln(K)$	-0.0190	0.0581	0.0054	0.0664
$ln(L)$	0.0765	0.0763	0.1801***	0.0815
East Germany	0.4726***	0.1916	0.4323***	0.1689
Exporting firm	0.3179***	0.1420	0.0628	0.1542
Foreign competition	0.3899***	0.1417	0.4614***	0.1417
Apprenticeship problem	-0.3447***	0.1361	-0.1777	0.1506
Sales balance$_{t-2}$	-3.0768*	2.3208	–	–
Sales balance$_{t-3}$	2.8709	2.4112	–	–
Constant	-0.1109	0.4815	-1.5688***	0.5215
	Wald tests for joint significancy			
	χ^2	p–value	χ^2	p–value
Factor inputs	2.5615	0.4643	10.9887	0.0118
Sector dummies	9.4246	0.3990	11.9664	0.2152
Sales balances	1.7612	0.4145	–	–
Entire set of identifiers	24.5091	0.0002	14.6881	0.0021
Entire sel. eq.	49.8257	0.0001	52.6838	0.0000
	Wald tests for joint significance: entire switching regression model			
Correlation coefficients	27.9919	0.0000	21.4551	0.0000
Entire switching regression	207.1882	0.0000	217.2835	0.0000

Table 4 displays estimation results for the selection equations of the endogenous switching regression model. A total of 411 observations was involved in the estimations.

density estimates for log labor productivity related to the parameter vector with reinforcement of group work *and* firms which actually conduct this form of workplace reorganization while the circled curve ('parameter vector w/o group work reinforcement') corresponds to the parameter vector without workplace reorganization *and* firms which enhanced group work. Mathematically, the triangled curve in Figure 1 is calculated from the fitted values $\boldsymbol{X_i\hat{\gamma}_{oc}}$ while the circled curve is calculated from the fitted values $\boldsymbol{X_i\hat{\gamma}_{noc}}$, where $\boldsymbol{X_i}$ includes only those firms with enhancement of group work.

In both Figures, Figures 1 and 2, the log labor productivity distribution for the regime with group work enhancement is situated to the right of the regime without workplace reorganization: group work enhancement has positive effects on

Table 5: Wald test for identity of the partial elasticities of ICT and non–ICT investment

	Test stat.	p–value
Group work		
W/ organizational change	0.1692	0.6808
W/o organizational change	0.2801	0.5967
Flattening of hierachies		
W/ organizational change	0.1566	0.9011
W/o organizational change	0.3825	0.5363

Table 5 presents the results of Wald test for identity of the partial elasticities of ICT and non–ICT investment.

Table 6: Means, medians and standard errors of the estimated log productivities

	Mean	**Median**	**Std. err.**
Group work			
w/ workplace reorganization	5.3434	5.3319	0.4785
w/o workplace reorganization	4.8753	4.8520	
Flattening of hierarchies			0.5659
w/ workplace reorganization	5.1507	5.1684	0.5426
w/o workplace reorganization	4.9911	4.9761	0.5352

Table 6 means, medians and standard errors of log productivities estimated on the basis of the switching regression model.

labor productivity.

Selection equation

The identifying variables exporting firms, presence of foreign competition, difficulties in recruiting qualified apprenticeships and the lagged sales balances are jointly highly significant. An unfavorable economic performance in the respective sectors leads to a decrease in the probability to introduce group work, implying that the financial restrictions problem overweighs the benefits of reorganization, at least in the short run. The set of input factors does not significantly affect firms' decision to introduce group work.

Results specific to the flattening of hierarchies

Productivity estimations

The results for the flattening of hierarchies as one form of workplace reorganization are quite similar to those obtained for the enhancement of group work: the output elasticities of the three input factors are insignificantly different from

one another across the two workplace reorganization productivity regimes. Although the output elasticity of labor appears to be substantially larger in the regime with workplace organization, the difference between the two parameters is insignificant.
The productivity differences arising from workplace organization are visualized in Figures 3 and 4 in the same fashion as for group work reinforcement. Both figures show that the gain in marked log labor productivity is lower for the flattening of hierarchies than for the introduction of group work. While median log productivity is larger if hierarchies are flattened, the tails of the log productivity distributions almost perfectly overlap.
Selection equation
The identifying restrictions are jointly highly significant. Firms faced by foreign competition are significantly more likely to flatten hierarchy levels than those not confronted with competitors from abroad. The input factors ICT–investment, non–ICT investment and labor are also jointly significant, with labor input having a highly significant and positive effect on the the probability to flatten hierarchies.

Table 6 summarizes the estimation results for the productivities by displaying means, medians and standard errors of the estimated log productivities. The distribution of the productivities is almost symmetric as indicated by the identity of means and medians. Labor productivity is larger if workplaces are reorganized. The labor productivities are measured with high precision, the standard errors only amount to a tenth of mean and median productivity.

To summarize, the estimation results underline that it is crucial to enlarge the discussion on the productivity effects of ICT by taking into account organizational change. They hence support earlier evidence on this count provided by as Black and Lynch (1997), Bresnahan et al. (2000) or Brynjolfsson and Hitt (2000).

5 Conclusions

This paper studies the effects of workplace organization on labor productivity in a simultaneous equations setting. A firm's decision to reorganize workplaces is assumed to depend upon the productivity differential with and without workplace reorganization net costs. An endogenous switching regression model is developed and estimated on a sample of 411 firms from the German business–related services sector. It turns out that workplace reorganization and labor productivity are in fact simultaneously determined.
Two forms of organizational change are considered: enhancement of group work and flattening of hierarchies.
Main empirical results are that workplace organizational change in the form of

enhanced group work and flattening hierarchies induces a positive shift in the distribution of labor productivity. These findings are in line with earlier studies not accounting for the potential simultaneity of workplace reorganization and labor productivity such as Black and Lynch (1997), Bresnahan et al. (2000) as well as Brynjolfsson and Hitt (2000).

Our estimates also show that workplace reorganization does not induce significant changes in the partial output elasticities of ICT–investment, non–ICT investment and labor. In accordance to Gordon (2000) and in contrast to Jorgenson and Stiroh (1999, 2000), we do not find significant differences between the partial productivity of ICT–capital and non–ICT capital.

A straightforward extension of the present analysis is the use of panel data to study the effects of workplace reorganization on labor productivity. It seems likely that workplace reorganization will fully reveal its effects on labor productivity with a time lag since it takes time for employees to adopt a new workplace organizational practice. As panel data are currently not available, this issue has to be left for further research.

Figure 1: Changes in the labor productivity distribution due to enforcement of group work: what if firms with group work enforcement had not undertaken organizational change (productivity measured in natural logarithms and in 1,000 German Marks)?

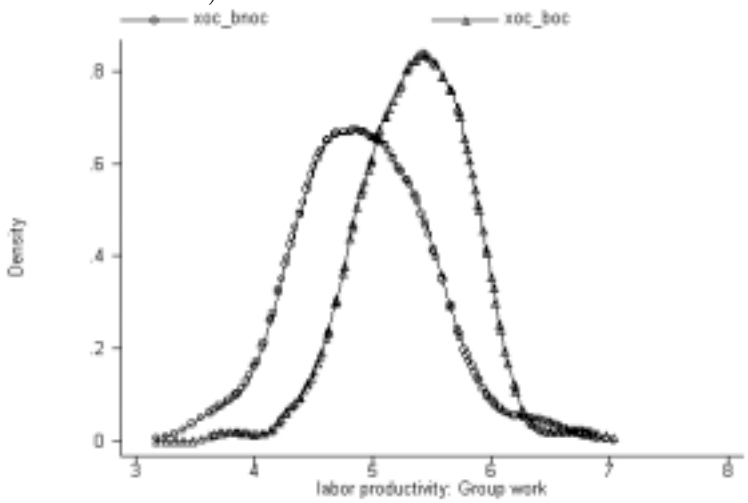


Figure 2: Changes in the labor productivity distribution due to enforcement of group work: what if firms without group work enforcement had undertaken organizational change (productivity measured in natural logarithms and in 1,000 German Marks)?

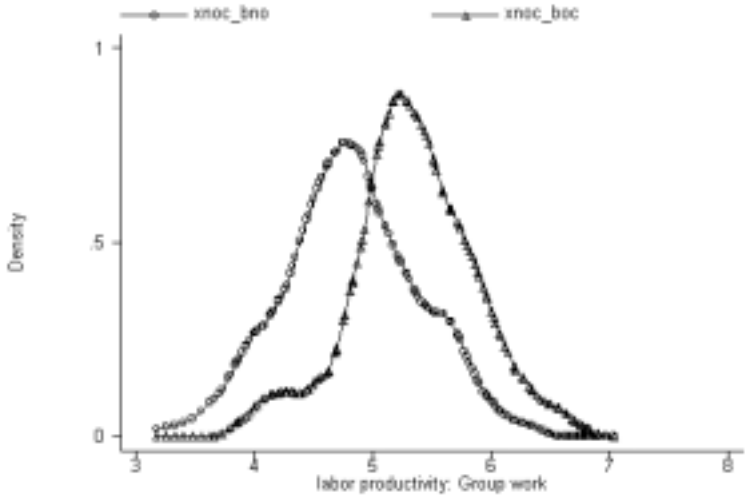


Figure 3: Changes in the labor productivity distribution due to flattening of hierarchies: what if firms with hierarchy flattening had not undertaken organizational change (productivity measured in natural logarithms and in 1,000 German Marks)?

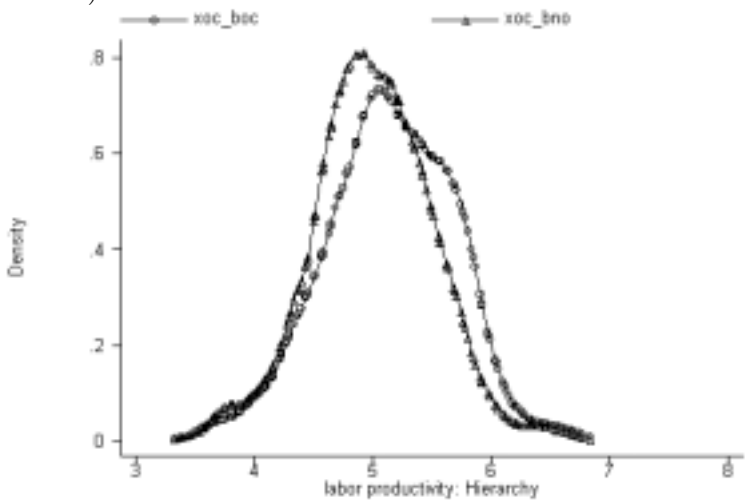
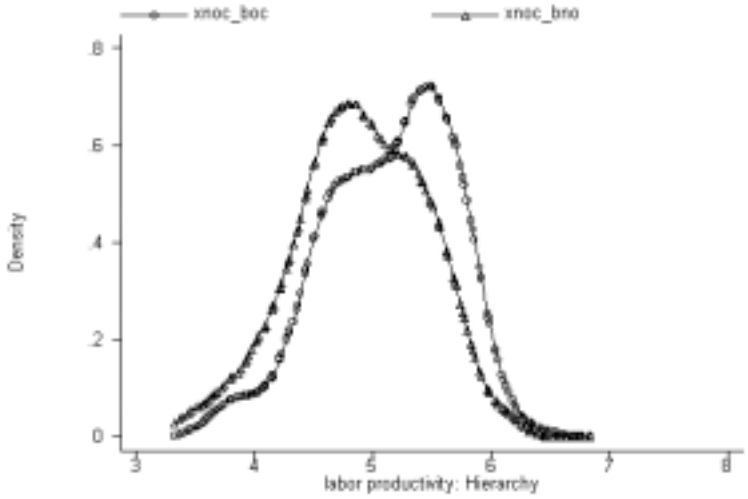


Figure 4: Changes in the labor productivity distribution due to flattening of hierarchies: what if firms without flattening of hierarchies had undertaken organizational change (productivity measured in natural logarithms and in 1,000 German Marks)?



6 References

Black, S. E. and L. M. Lynch (1997), How to Compete: The Impact of Workplace Practices and Information Technology on Productivity, *NBER working paper*, No. W6120.

Bresnahan, T., E. Brynjolfsson and L. Hitt (2000), Information Technology, Workplace Organization and the Demand for Skilled Labor: Firm–level Evidence, forthcoming in *Quarterly Journal of Economics*.

Brynjolfsson, E. and L. Hitt (1996), Paradox Lost? Firm-level Evidence on the Returns to Information Systems Spending, *Management Science*, 42,4,541–58.

Brynjolfsson, E. and L. Hitt (2000), Beyond Computation: Information Technology, Organizational Transformation and Business Performance, *Journal of Economic Literature*, Vol. 14, No. 4, 23–48.

Chennels, L., and J. van Reenen (1999). Technical change and the structure of employment and wages: A survey of the micro–econometric evidence, IFS working paper.

Crowston, K. and T. W. Malone (1988), Information Technology and Work Organization, *Handbook of Human-Computer Interaction*, chapter 49, 1051–1070.

Dewan, S. and C.-K. Min (1997), The Substitution of Information Technology for Other Factors of Production: A Firm Level Analysis. *Management Science, 43 (Dec.)*, 1,660–1,675.

Greenan, N. and J. Mairesse (1996), Computers and Productivity in France: Some Evidence, *NBER Working Paper* No. 5836.

Greene, W.H., 1997, Econometric analysis. Prentice–Hall, Upper Saddle River.

Hax, H. (1998). Anforderungen an die Statistik zur Konjunkturbeobachtung und Konjunkturprognose durch den Sachverständigenrat. *Allgemeines Statistisches Archiv, 82*, 15–24.

Huselid, M. A. (1995), "The Impact of Human Resource Management Practices on Turnover, Productivity, and Corporate Financial Performance", *Academy of Management Journal*, 38:3, 635–672.

Ichniowski, C., K. Shaw and G. Prennushi (1997), "The Effects of Human Resource Management Practices on Productivity: A Study of Steel Finishing Lines", *American Economic Review*, 87:3, 291–313.

Jorgenson, D. W. and K. J. Stiroh (1999). Information Technology and Growth, *Economics of Innovation and New Technology*, 3, 295–316.

Jorgenson, D. W. and K. J. Stiroh (2000). Raising the Speed Limit: U.S. Economic Growth in the Information Age, mimeo, Harvard University, Cambridge, Mass.

Kaiser, U. (2001). Structural Changes in the German Service Sector: Innovation, Employment, Firm Performance. ZEW mimeo; forthcoming: Springer–Verlag Heidelberg.

Kaiser, U. , M. Kreuter and H. Niggemann (2000). *The ZEW/Creditreform Business Survey in the Business-related Services Sector: Sampling Frame, Stratification, Expansion and Results.* ZEW discussion paper 00–22.

Leavitt, H. J. and T. L. Whisler (1958), Management in the 1980s, Harvard Business Review, 36, 41–48.

Licht, G. and D. Moch (1999), Innovation and Information Technology in Services, *Canadian Journal of Economics* 32, 363-383.

Lichtenberg, F. (1995), The Output Contributions of Computer Equipment and Personnel: A Firm-Level Analysis, *Journal of Economic Innovations and New Technologies* 3, 201-217.

Maddala, G.S. (1983), *Limited Dependent and Qualitative Variables in Econometrics*, Cambridge, Cambridge University Press.

Miles, I. (1993). Services in the New Industrial Economy. *Futures, July/August 1993*, 653–672.

Milgrom, P. and J. Roberts (1992), "The Economics of Modern Manufacturing: Technology, Strategy, and Organization.", *American Economic Review*, 80:3, 511–528.

Niggemann, H. (2000). Die volkswirtschaftliche Bedeutung von Dienstleistungen und der Beitrag des Mannheimer Innovationspanels und der ZEW/Creditreform Konjunkturumfrage zu ihrer Darstellung. *Wirtschaft und Statistik, 7*, 541–550.

Triplett, J. E. (1999), The Solow productivity paradox: what do computers do to productivity?, *Canadian Journal of Economics*, 32,2, 309–334.