Discussion Paper No. 01-32

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Abstract: This paper analyzes the relationship between investment in information and communication technologies (ICT), non–ICT–investment, labor productivity and workplace reorganization. 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: introduction of group–work and flattening of hierarchies. Empirical evidence is provided for a sample of 411 firms from the German business–related services sector.

We develop and estimate a model for labor productivity and firms' decision to re-

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organize workplaces that allows workplace reorganization to affect any parameter of the labor productivity equation. Our general and flexible methodology allows to properly take account of strategic complementarities between the input factors and workplace reorganization. The estimation results show that changes in human resources practices do not significantly affect firms' output elasticities with respect to information and communication technologies (ICT), non–ICT–capital and labor although most of the point estimates of the individual output elasticities and of the control variables for observable firm heterogeneity are larger if workplace reorganization is realized. We therefore apply Kernel density estimation technique and demonstrate that for firms with organizational change the *entire* labor productivity distribution shifts significantly out to the right if workplace reorganization takes place, indicating that workplace reorganization induces an increase in labor productivity that is attributable to complementarities between the various input factors and workplace reorganization. By contrast, firms without organizational change would not have realized significant productivity gains if they had reorganized workplaces.

JEL classification: $C25, D24$

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

1 Introduction

The swift development of information and communication technologies (ICT) as well as the declining prices for its use have considerably enhanced the diffusion of ICT during the last few years. As a consequence, the impact of ICT on productivity has become a broadly discussed topic in management sciences and economics. Several studies find empirical evidence for positive productivity effects of ICT at the firm level (Brynjolfsson and Hitt (1996); Lichtenberg (1995); Greenan and Mairesse (2000); Licht and Moch (1999)). Although it seems reasonable that ICT also has an indirect effect on labor productivity by enabling firms' reorganization of workplaces, researchers have only recently become interested in the joint effects of workplace organization and ICT on labor productivity. Studies like that of Black and Lynch (2001), Brynjolfsson and Hitt (2000) and Bresnahan, Brynjolfsson and Hitt (2002) find empirical evidence that ICT and workplace reorganization have in fact positive and significant effects on labor productivity.

A flaw of these studies is that they assume a unidirectional relationship between labor productivity and workplace reorganization. They take the view that workplace reorganization affects labor productivity, but ignore a potential reverse causality since a main reason for firms to reorganize workplaces is to increase labor productivity. Such a simultaneity renders the economic interpretation of the results presented in earlier studies questionable and casts doubt on any recommendations for management practices based on them.[1]

The merits of this paper are twofold. First, it takes the potential simultaneity between labor productivity and firms' decisions to reorganize workplaces into account by estimating an endogenous switching regression model for a sample of 411 firms from the German business–related services sector. Second, it allows for complementarities in firms' organizational design, e.g. it allows workplace reorganization to change any parameter of the production function. We hence apply a general and flexible econometric methodology.

In our model, firms are assumed to reorganize workplaces if the productivity gains arising from the reorganization exceed the associated reorganization costs. The reorganization decision defines two labor productivity equations — or 'regimes' — one which involves firms with workplace reorganization, and another regime including firms without such a change in human resources management. Besides taking a potential simultaneity into account, the switching regression model also allows workplace reorganization to change the entire set of partial productivity elasticities instead of a priori restricting workplace reorganization to act as a productivity shift parameter in the productivity equations, as earlier studies do. Our estimation results indeed indicate that it is worthwhile to allow for a more flexible effect of workplace reorganization on labor productivity.

[1]In econometric terms, the parameter estimates of existing studies are likely to suffer from a simultaneity bias which leads to inconsistent parameter estimates.

Moreover, this paper provides evidence for two distinct types of workplace reorganization: enhancement of group–work, established by 39 per cent of the firms in our sample, and flattening of hierarchy levels, introduced by 28 per cent of the analyzed firms.

Our estimation results clearly indicate that labor productivity and workplace reorganization are simultaneously determined. We find that the *individual* output elasticities of ICT–investment, non–ICT–investment and labor do not significantly differ between firms with and without workplace reorganization and that there are insignificant differences in the returns to scale between the two regimes. The point estimates of the partial output elasticities of labor and non–ICT–investment are, however, larger for the set of firms which conducted a workplace reorganization, but the coefficients do not differ significantly from each other.

We conduct a counter-factual analysis related to the questions: (i) what would have been the effect of workplace reorganization on productivity for a firm without changes in human resources practises if it had changed the organization of workplaces and (ii) what would have happened to the productivity of a firm that changed the organization of workplaces if it had not changed it? We visualize the *joint* differences in the point estimates by plotting the entire labor productivity distributions of firms with workplace reorganization and of firms without workplace reorganization using Kernel density estimation. Our results indicate that the firms in our sample on average reached the right decision: only those firms that reorganized workplaces actually gained from the reinforcement of group work or the flattening of hierarchies while firms that did not introduce changes in workplace organization would not have realized gains in productivity.

This paper proceeds as follows: Section 2 briefly reviews the existing literature. Section 3 presents the theoretical framework as well as the empirical model. Section 4 introduces the data set, Section 5 presents and interpretes estimation results and Section 6 concludes.

2 Earlier research

Until recently, two main strands of literature have dealt with the relation between ICT–investment, organizational change and productivity. One branch concentrates on the impact of ICT-investment on organizational change. 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 example, 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 loosely 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 branch of the literature mainly deals with the impact of workplace organization or human resources management on labor productivity (Black and Lynch (1996); Eriksson (2003); Huselid (1995); Ichniowski, Shaw and Prennushi (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 often requires a restructuring of the firm in order to use this new system efficiently. Thus, it appears likely that workplace reorganization 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 (2001), who analyze the productivity effects of several workplace practices, ICT and human capital using cross sectional and panel data estimation on a sample 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. (2002) also find empirical evidence that ICT, workplace reorganization as well as new products and services positively affects the demand for skilled labor and firms' labor productivity. Their analysis is based on a data set of 300 large U.S. firms from manufacturing industries and services.

3 Theoretical background

3.1 Complementarities in firm strategies

It is likely that firms with organizational changes do not only differ from other firms with respect to their organizational form but also in various other respects such as skill mix or investment strategies. Milgrom and Roberts (1990) demonstrate that firms need to implement computer technology as part of a system or cluster of organizational change. This argument of *strategic complementarity* has been further advanced in studies by Brynjolfsson and Mendelson (1993) as well as by Radner (1993). It might thus be too restrictive to assume that firms produce according to the same production function independent of the way workplaces are organized. Considering the effect of workplace reorganization to simply change the constant term in a production function neglects that workplace reorganization is very likely also to change firms' strategies with respect to skill mix and investment and that these changes may have impacts on the labor productivity of firms, i.e. that an organizational change might enable a more efficient use of the input factors labor, ICT–capital and non–ICT–capital. This constitutes the main hypothesis of this paper:

> Main hypothesis: Workplace reorganization does not only act as a shift parameter in the production function but changes — due to strategic complementarities between workplace reorganization and the input factors — the partial productivities of labor, ICT–capital and non–ICT–capital as well.

We test our main hypothesis by simultaneously estimating two labor productivity equations — one for firms with workplace reorganization and one for firms without workplace reorganization. In a second step, we compare the labor productivity distributions by applying Kernel density estimation technique. Changes in the entire shape of the labor productivity distribution due to workplace reorganization point at complementarities between workplace reorganization and the production factors.

Empirical evidence on the relationship between ICT–investment and organizational change is provided for instance by Bresnahan (1999) and Bresnahan et al. (2002). Both papers suggest that investment in ICT *enables* changes in work organization. In a case study context, Brynjolfsson, Renshaw and van Alstyne

(1997) demonstrate that even productivity *losses* might occur if investment in ICT does *not* go along with changes in firms' organizational structure.

Brynjolfsson and Hitt (2000) also stress the complementarity between human capital and workplace organization that in turn jointly improve productivity and cost efficiency. Indeed, it is fairly well documented that workplace reorganization goes along with an upskilling of the labor force in the sense that high skilled labor and workplace reorganization are strategic complements (Black and Lynch (2001); Bresnahan et al. (2002)).

3.2 Forms of organizational change

In this paper, we consider two forms of organizational change: (i) enhancement of group work and (ii) flattening of hierarchies. Both the enhancement of group work and the flattening of hierarchies are closely related to what Bresnahan et al. (2002, p. 350) term 'decentralized workplace organization', meaning that the authority of individuals and teams is enhanced. The authors indeed find that higher ICT–levels go along with higher degrees of decentralization of workplace organization.

By motivating employees and by increasing their identification with their companies (Ichniowski et al. (1997)), firms intend to increase productivity. More specifically, organizational changes are feasible means to reduce production cost and to improve product quality (Brynjolfsson and Hitt (2000); Davenport (1994); Davenport and Short (1990); Hammer (1990);). In our context, both organizational changes, enforcement of group work and flattening of hierarchies, are likely to have an effect on costs as well as on quality since by improving information flows in the production of services, customers are served more efficiently (reducing cost) and faster (improving service quality).

Traditionally, hierarchical organizational structures are said to reduce communication costs compared to flat hierarchies (Malone, Yates and Benjamin (1987); Radner (1993)). In the Milgrom and Roberts (1990) model, communication costs are driven towards zero by ICT, so that more direct interaction between employees is enhanced without causing higher cost. Flattening of hierarchies might affect the motivation of workers with the total effect being unclear: on the one hand, a removal of hierarchical structures might motivate workers on the low end of the hierarchy ladder while having an inverse effect on those who loose power due to the abolishment of hierarchy levels. The total effect of hierarchy flattening hence hinges upon the ratio of 'winners' and 'losers' as well as on the relative productivity of both types of workers. Empirical evidence provided by Bresnahan et al. (2002) suggests that firms with a decentralized organizational structure exhibit a higher partial productivity of ICT than firms with a centralized structure, thus underscoring the initial Milgrom and Roberts (1990) argument of complementarities between organizational structure and ICT.

While the flattening of hierarchies affects the general flow of information within a firm, the reinforcement of team work mainly affects the flow of information concerning specific projects or targets. The latter also involves employees of different hierarchy levels, at least in the knowledge intensive business–related services sector that this paper is concerned with. This in turn implies an improved feedback and a higher identification with the work to be completed. These positive effects might be counteracted by inefficient organization of the team and by upper managements' difficulties to transmit information to the team members — a problem that might be solved by using communication and organization software as pointed out by Brynjolfsson and Hitt (2000, p. 24): "a significant component of the value of IT is its ability to enable complementary organizational investments such as business processes and work practices."

Hierarchy flattening and team work both affect — although in different ways — (i) information flow and (ii) worker motivation — and this is why we do not expect large differences between the effects of these two kinds of workplace organizations on the productivity parameters.

3.3 Empirical model

In order to formalize the considerations of sections 3.1 and 3.2, the following model is used: we assume that firm i produces according to a Cobb–Douglas production technology. Output y_i is a function of ICT–capital, ICT_i, non–ICT–capital, K_i, and labor, L_i, and a set of variables capturing observable firm heterogeneity, often termed 'observable differences in production efficiency', which are summarized in variable A_i:

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

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

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

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

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

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

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

For firms not conducting an organizational change, labor productivity is

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

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 in an organizational change, C_i. Thus, the latent variable

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

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 optimization error and a represents the effect of the productivity gains from workplace reorganization on the reorganization decision. If $a = 0$, the reorganization decision is unaffected by the productivity differences.

The selection mechanism for observing a workplace reorganization is

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

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

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

where $\varepsilon_i \ = \ a(u_{ioc} \ - \ u_{inoc}) \ + \ v_i$ 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

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

respectively, 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:

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

and likewise:

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

Denoting $\rho_{ORG,ln(\frac{y_i}{L_i})_l}$, the correlation between u_{il} and ε_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]

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

If $\rho_{ORG,ln(\frac{y_i}{L_i})_{oc}} = \rho_{ORG,ln(\frac{y_i}{L_i})_{noc}} = 0$, the productivity equations could be estimated by OLS and the selection equation could be estimated by a probit model.

[2]The GAUSS code that we used for the estimation of the model is downloadable from the internet at http://www.ulrichkaiser.com/software. The website also provides codes for the Monte Carlo study we used for testing our estimator, a documentation of the Monte Carlo simulations and a trial data set that consists of simulated variables.

4 Data

We use data taken from the 'Service Sector Business Survey', a quarterly business survey in the business–related services sector which is collected by the Centre for European Economic Research (ZEW, Zentrum für Europäische Wirtschaftsforschung) in cooperation with Germany's largest credit rating agency Creditreform since June 1994.[3] The ZEW sends out a one page questionnaire every three months to about 3,500 firms belonging to the business-related services sector.[4] The survey is constructed as a panel. It is a 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, Kreuter and Niggemann (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

[3]One of the authors, Ulrich Kaiser, was head of the project team by the time the survey was conducted.

[4]Following Miles (1993), 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).

answering questions concerning the 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 cannot presently be provided.[5]

In particular, the relevant question in the survey is: "Did one of the following changes or reforms take place within your firm during the past three years?". The list of possible answers consists of (i) enhancement of group–work and (ii) flattening of hierarchies. Firms have three answering possibilities: (i) yes, (ii) no and (iii) don't know. Although the question appeared to have been well understood by the survey participants,[6] we clearly do not know anything about the degree of radicalness of the organizational change. It is unclear, for example

[5]Moreover, the SSBS is a very versatile data set where firms take part in an irregular basis (a point to which we shall return to at the beginning of Section 5) so that even if panel data was available, unobserved heterogeneity could not be taken into account since we ended up with a very tiny fraction of firms for which data is available for more than two periods. The problem is even more severe since we combine data from adjacent survey waves.

[6]A 'pretest' (a test survey that involved 19 firms) revealed that all participants had the same notion of the two types of organizational change. We also interviewed 15 of the firms that eventually took part in the SSBS survey wave and found the same result.

whether firms have changed the organization of one department only or of the entire firm. This is a caveat of our study.

We supplement the information contained in the 26th wave of the SSBS with 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 did not respond to the 24th wave, these firms cannot be considered in the analysis. A check for systematic differences in the anatomy of firms (with respect to firm size, sector affiliation, regional affiliation, ICT–investment and non–ICT–investment) which have to be left out due to unit non–response indicates that these firms are missing at random.

Our analysis starts with some descriptive evidence on ICT–investment, non–ICT–investment, labor input and workplace reorganization. Table 1 displays the share of firms which conducted one of the two types of workplace reorganization. Group work reinforcement is the more important type of workplace reorganization, with a share of 39 per cent of the firms in the sample, compared to a share of 28 per cent for the flattening of hierarchies. The order of importance replicates the degree of radicalness of the 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.

Insert Table 1 about here!

Table 2 displays the quantiles, means and standard deviations of the most important continuous variables used in the estimation of labor productivity: ICT–investment, non–ICT–investment (both in 1,000 DM), output (proxied by annual sales in 1,000 DM), total employment and productivity (output per worker).[7] The firms in our sample are quite small compared to mean and median firm employment in German manufacturing industries (Janz and Licht (1999)). The largest firm in our sample has 1,300 employees, the smallest has one employee. Interestingly, all firms have positive ICT–investment what might reflect the fact that ICT-investment as a share of total investment are on average larger in the services sector than in the manufacturing sector.[8] On the average across firms, a worker produces 299,300 DM output (i.e. sales) per year with a median of 185,400 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 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.

[7]The DM/Euro exchange rate is 1.95583.

[8]See also Table A in the Appendix.

Insert Table 2 about here!

5 Empirical results

5.1 Specification

The implementation of our empirical model is straightforward. Labor productivity is calculated as the ratio of total sales to the total number of employees. Non–ICT–capital is measured as investment in physical capital, ICT–capital 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 using the perpetual inventory method. The SSBS, however, is a very volatile panel data set. Firms usually take part in the survey 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 (Kaiser (2001)).

Observed productivity differences across firms, as represented by the term 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 adjusting quickly to changes in the international market environment, (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. The latter variable is supposed to indicate whether a company has a general problem in finding qualified personnel, implying that it might not be able to adjust its workforce to a new organizational form.

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 within industries by calculating sales balances, i.e. the share of firms with positive sales development minus the share of firms with negative sales development in the respective wave of the SSBS. We account for sector–specific, region–specific and firm size–specific differences by calculating the sales balances individually for each of the business–related sectors and for East and West Germany. We test for the optimal lag length using Likelihood Ratio tests. It turns out that sales balances of lag length two quarters and three quarters 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 are not determined a priori since a negative sales development may cause firms to plan restructuring but also restricts financial flexibility.

In econometric terms, the dummy variables for exporting firms, for firms faced by foreign competitors and for firms with difficulties in recruiting qualified apprenticeships as well as the sales development variables are the identifying restrictions of equation (8).

Insert Table 3 about here!

Insert Table 4 about here!

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

5.2 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.[9]

The 'partial productivity' parameters, the coefficients of $ln(ICT)$, $ln(K)$ and $ln(L)$, capture the percentage change in labor productivity induced by a one per cent change in the corresponding production factor. For example, in the case of group work enhancement, a one per cent increase in ICT–investment induces a 0.1515 per cent increase in labor productivity, a one per cent increase in non–ICT–investment leads to a productivity increase of 0.1909 per cent and a one per cent increase in employment leads to an increase in labor productivity of 0.652 per cent. We obtain quite similar estimates for the corresponding specifications with respect to hierarchy flattening. This means that the 'payback' of investments is higher for labor than for capital. Labor, however, is more expensive than ICT-equipment such that the 'real' net payback of these investments could only

[9]Note that for labor input, the estimated coefficients displayed in Table 3 correspond to $\gamma - 1$, so that adding 1 to the estimated coefficients yields the partial output elasticity of labor.

be calculated reliably if data on costs and profits were available. However, this information is, unfortunately, not at our disposal.[10]

The point estimates of the partial productivity estimates of investment and labor are generally larger in the regime with organizational change than in the regime without the change in human resources management, whereas the estimated elasticity with respect to ICT-investment turns out to be smaller in the regime with organizational change. Identity of these parameters, however, cannot be rejected at the usual significance levels, as shown in Table 3. Indeed, identical returns to scale for the two productivity regimes cannot be rejected either. Hence, workplace reorganization has an insignificant effect on the partial output elasticities of ICT–investment, non–ICT–investment and labor input.

Even though the point estimates of the constant term, the dummy variable for East German firms and the sector dummy variables tend to be larger in the regime with workplace reorganization than in the regime without workplace reorganization, identity of these parameters between the two workplace reorganization

[10]Brynjolfsson and Hitt (1996, p. 550) for example calculate the net marginal product of computer capital to lie between 48 and 67 per cent, depending on the assumptions about the depreciation rate of computer capital. Moreoever, they mention the problem of taking account of costs such as taxes, adjustment costs, etc. Since we have no information about profits and costs, but observe only sales, and since we do not observe ICT–capital but ICT–investment, we prefer to refrain from calculating 'real' payback to IT.

regimes cannot be rejected at the usual significance levels as well. Consequently, identity of the entire parameter vectors of the two regimes cannot be rejected at the usual significance levels.

Interestingly, the point estimates of the partial output elasticities are almost of the same magnitude for both types of workplace reorganization, group work enhancement and hierarchy flattening. This means that the two forms of workplace reorganization do not have strikingly different effects on the partial productivities of ICT–investment, non–ICT–investment and labor. The factor inputs, the set of sector dummies as well as the entire set of explanatory variables are clearly jointly significant for both regimes with and without organizational change and for both types of workplace reorganization. There is only one exception referring to the set of sector dummies in the case of group work reinforcement and the regime with organizational change.

In order to visualize the *joint* effects of the differences in the partial output elasticities and the firm heterogeneity parameters, we compare Kernel density estimates of the conditional labor productivity distributions in the two regimes. These joint effects are displayed in Figures 1 and 2 for group work and in Figures 3 and 4 for the flattening of hierarchies.

Insert Figures 1 and 2 about here!

Insert Figures 3 and 4 about here!

Instead of just considering the point estimates related to the input factors, these figures show the *joint* productivity effects of workplace organization arising from changes in the output elasticities of the input factors *and* from the changes in the observable firm heterogeneity parameters. In addition, the selectivity effect resulting from the firms' decision whether or not to reorganize workplaces is taken into account.

The idea behind the figures is to consider the same firms — those with workplace reorganization (Figure 1 and Figure 3) and those without workplace reorganization (Figure 2 and Figure 4) — under the two different workplace reorganization regimes. In order to control for the fact that firms with organizational change might be systematically different from those without organizational change and thus might differ in their decision to engage in workplace organization, the productivity distributions are estimated conditional on the choice of firms concerning workplace reorganization. Details on the econometrics are displayed in the Appendix.

The triangled curve in Figure 1 represents Kernel 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 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 $\boldsymbol{X_i}\hat{\boldsymbol{\gamma}}_{\boldsymbol{oc}}$ while the circled curve is calculated from the fitted values $\boldsymbol{X_i}\hat{\boldsymbol{\gamma}}_{\boldsymbol{noc}}$, where $\boldsymbol{X_i}$ includes only those firms with enhancement of group–work, plus the selectivity parameter resulting from the choice of the firms whether or not to engage in workplace reorganization, respectively.

In all figures, the log-labor productivity distribution *with* organizational change is situated to the right of the regime without workplace reorganization. However, the productivity differentials in the log-labor productivity between the two regimes are much larger for firms with organizational change. This means that the firms with group work enhancement or hierarchy flattening are clearly better off compared to the hypothetical case without workplace reorganization. By contrast, those firms without organizational change would not have gained much if they had reorganized their workplaces. Thus, it seems that in average the firms take "the right decision" with respect to organizational change since reorganization only pays off if the associated productivity gains are larger than the reorganization cost.

The results of the kernel density estimations might explain to some extent the insignificancy of the difference of the estimated coefficients in the two regimes according to Table 3 since those do not consider hypothetical productivity differentials.

The labor productivity effects for hierarchy flattening are on average larger than those for group work reinforcement. For both types of organizational change, a t–test indicates a significant shift in the mean log-labor productivity between the regimes with and without workplace reorganization. Table 5 displays the corresponding test results.

Insert Table 5 about here!

Interestingly, if workplace reorganization is considered as a simple productivity shift dummy variable, comparable to existing studies (e.g. Black and Lynch (2001); Bresnahan et al. (2002); Brynjolfsson and Hitt (2000)), we do not find significant effects of workplace reorganization on labor productivity. Indeed, when a simple linear regression of labor productivity on a dummy variable for the different types of workplace reorganization and the same explanatory variables as in our model is run, the effects of workplace reorganization on labor productivity are insignificant.[11] This indicates that workplace reorganization induces a change in the *entire* set of output elasticity coefficients and in the set of variables capturing observable firm heterogeneity, so that inserting a dummy variable for

[11]The point estimate (standard errors in parentheses) corresponding to the dummy variable for the reinforcement of group–work is 0.0862 (0.0818). For the flattening of hierarchies, the coefficient of the dummy variables is 0.0364 (0.0910).

organizational change in a productivity equation may not have fully revealed the effects of organizational change on productivity.

A potential alternative to our approach would be to include interaction terms between the input factors and the dummy for organizational change into the estimation in order to take account of potential complementarities. Proceeding this way, however, would neglect the simultaneity between organizational change and labor productivity revealed by applying the endogenous switching regression model. Hence, we consider the endogenous switching regression model and the counter-factual analysis of productivity differentials as the appropriate and econometrically correct way of estimation for this issue.

According to Bresnahan and Trajtenberg (1995), ICT can be interpreted as a 'general purpose technology' which facilitates complementary innovations. Thus, one might suppose that the contributions of ICT-capital to productivity are significantly larger than those of non–ICT–capital. However, as results of Wald tests for identity of the partial output elasticities of ICT–investment and non–ICT–investment for the four productivity estimations show, see Table 6, identity of the coefficients α and β cannot be rejected at the usual significance levels. One reason for this finding might be that not all benefits of ICT use are captured by the production elasticity of ICT. Since ICT enables complementary organizational investments such as those proxied by the workplace organization variables in our study, some fraction of the productivity contribution of ICT-investment might be absorbed by other transmission mechanisms. A second reason might be the use of ICT-investment as a measure of the ICT-capital stock. Although in part justifiable by the fast depreciation rate of ICT, it may capture the capital stock only insufficiently (the same is true of course for the capital variable as well). Finally, due to the cross-sectional character of our data, we are not able to account for lagged effects of ICT on productivity, an issue that is highlighted for example by Brynjolfsson and Hitt (2000) who state on p. 33 of their paper that "... the effects of information technology are substantially larger when measured over longer time periods" and if productivity growth is considered rather than productivity levels.

Insert Table 6 about here!

5.3 Separation equations

An important result of the two reduced form separation equations, as displayed in Table 4, are that the identifying restrictions are jointly highly significant. This suggests, together with the result that the individual coefficients carry the expected signs, that we have chosen good proxy variables for reorganization costs. A second indicator for the validity of our exclusion restriction is the fact that the exclusion restrictions turn out to be both separately (with only two exceptions) and jointly insignificantly different from zero if we insert them into the level equations.[12]

Turning to the individual coefficient estimates, we find that exporting firms and firms facing foreign competition are significantly more likely to reorganize workplaces than non–exporters and firms without foreign competitors in the home market. This result seems reasonable since firms that are faced with foreign competition are forced to produce efficiently in order to stay competitive on international markets. Reorganizing workplaces may be one factor within a whole set of complementary strategies such as investing in ICT in order to improve efficiency and productivity.

Firms with problems in hiring qualified apprentices are less likely to change workplace organization. This is in line with our view that difficulties in finding qualified apprentices is a good indicator for having difficulties in hiring qualified personnel in general which in turn implies difficulties in adjusting the workforce to a new workplace organizational form.

A favorable economic performance in the second–last quarter leads to a decrease

[12]Note that there is no formal test for the validity of the exclusion restrictions in this three equations simultaneous equations setting. What we did here is to separately estimate the productivity equations for each of the workplace reorganization regimes and to include the exclusion restriction in these productivity equations. If they turn out to be insignificant, this indicates — but does not formally prove — that they are truly exogenous to labor productivity.

in the probability of enhancing group work. The set of input factors does not significantly affect firms' decision to enforce group work but has a highly significant effect on the decision to flatten hierarchies. Unsurprisingly, larger firms tend to flatten hierarchies more often than smaller firms since they have more potential to flatten hierarchies. Sector affiliation does not play a significant role in the decision of reorganizing workplaces. East German firms have a significantly larger probability to reorganize workplaces than their West German competitors. This might be due to the fact that East German firms had to go through strong structural changes after the reunification in 1990 and thus might be generally more flexible than their West German counterparts. On the other hand, a lot of East German firms are still very young and thus might be more open–minded with respect to new organizational forms.

The parameters ρ_1 and ρ_2 measure 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.283-284). The correlation coefficients are jointly significant in all of the equations, indicating that treating workplace reorganization as truly exogenous for labor productivity is inappropriate. While the correlations between the selection equations and the level equations with workplace reorganization are insignificant, highly significant correlations exist for the selection equations and the productivity equations without workplace reorganization. The negative signs of the correlation coefficients indicate that, consistent with our model, an unanticipated productivity shock leads to a decrease in firms' propensity to reorganize workplaces.

Both the level and the selection equations are precisely measured, as indicated by the highly significant tests for joint significance of the entire parameter vectors.

Table 7 summarizes the estimation results with respect to log-labor productivity by displaying means, medians and standard errors of the estimated log productivities unconditional on the choice of organizational change. The distribution of log-labor productivity is almost symmetric, as indicated by the similarity of means and medians. Log-labor productivity is considerably larger if workplaces are reorganized. The standard errors only amount to a tenth of mean and median productivity, indicating that log-labor productivity is measured with high precision.

Insert Table 7 about here!

5.4 Organizational implications

There are two substantive findings that directly relate to the organization of firms. The first finding relates to the complementarity between organizational change and production factors, the second one concerns the small differences in the productivity effects of hierarchy flattening and the enhancement of group work.

The organizational implication of our complementarities finding is trivial (but a truism) that directly follows from the definition of complementarities: it is more profitable to invest in a multitude of complementary activities instead of focussing on just one activity. Translated to our application this means that firms should not only invest in labor and capital, but should attempt to accompany these investments by appropriate organizational changes.

Our second finding with respect to organizational implications is the small difference between the labor productivity effects of hierarchy flattening and group work enhancement. As pointed out in Subsection 3.2, both types of organizational changes affect information flows and worker motivation so that these two effects actually induce the positive labor productivity effects. That means that other types of organizational change that come with improved information flows and improved worker motivation could lead to equally large gains in productivity.

5.5 Caveats

Before summarizing and commenting on the organizational implications of our findings, some words of caution are in order. Our paper has four main caveats that all are due to binding data restrictions. (i) *Measurement of workplace reorganization:* we only observe whether a firm has conducted a workplace reorganization and do not know anything about the degree of radicalness of the reorganization. There might hence be differences even within the different form of workplace reorganization that we do not properly account for. (ii) *Generalizability:* Our analysis is concerned with the German business–related services sector. This sector differs markedly from other sectors, for example with respect to ICT use, an issue that is highlighted by Table A in the Appendix.[13] We therefore believe that our results cannot directly be carried over to other sectors since, for instance to manufacturing industries which are characterized by much more heterogeneity regarding e.g. their investment strategies than firms from the business–related services sector. By the same token we believe that our results are generalizable to the business-related services sectors of other OECD countries. (iii) *Cost variables:* We do not directly observe reorganization cost and use proxy variables instead. These proxy variables definitely do not cover all aspects of reorganization cost. They do, however, a good job in identifying the estimation equations

[13]The table is taken from Bertschek and Fryges (2002), who use German data based on a representative survey of the year 2000 which did not contain any information on workplace reorganization. In that survey, the business-related services comprise the industries: computer and telecommunication services, technical services and other business services. As the table shows, business–related services industries according to this definition are characterized by a relatively intensive use of ICT compared to some other industries. The heterogeneity with respect to ICT as a share of total investment is much bigger across the industries of the manufacturing sector.

which in turn justifies our variable selection. (iv) *Unobserved heterogeneity:* We do know, at least since the lesson taught by Brynjolfsson and Hitt (1995), that taking unobserved heterogeneity into account can markedly affect productivity estimation results. Our data is cross–sectional only so that we cannot model unobserved heterogeneity by using fixed effects estimation. The heterogeneity of the business–related services sector is, however, as already mentioned, less dramatic than in manufacturing industries (Kaiser 2002, Ch. 2) so that this problem might be of minor importance in this study.

A last and at least potential drawback of our paper that is unrelated to data and measurement issues is that we assume a Cobb–Douglas production technology which is along the lines of much of the literature and which is particularly often applied in the literature on the productivity effects of R&D as well as on the productivity effects of ICT, as for example by Brynjolfsson and Hitt (1995, 1996). Using a Cobb–Douglas specification implies an elasticity of substitution of unity between the input factors by construction and does not take account of the possibility that organizational change might vary the elasticity of substitution between input factors, for example between labor and ICT. A popular alternative to the Cobb–Douglas production function is the Translog approach which is more flexible in terms of elasticities of substitution. In the estimation of such a Translog production function we would encounter the well-known problem of high collinearity between the input factors which, coupled with our relatively low number of observations, made our Translog estimates implausible e.g. with negative mean production elasticities so that we believe that our restricted Cobb–Douglas specification is more reliable than the Translog specification. Brynjolfsson and Hitt (1995), for example, apply both specifications, Cobb–Douglas and Translog, to a data set of 1185 U.S. firms. The estimated elasticities resulting from the Translog specification turn out to be comparable to those of the Cobb-Douglas specification (p. 192 of their paper).

With this caveats in mind, our main conclusions from the estimation results are the following: the estimation results emphasize that, in line with Black and Lynch (2001), Bresnahan et al. (2002) and Brynjolfsson and Hitt (2000), the enlargement of the discussion on the productivity effects of ICT by taking into account organizational change is crucial. Moreover, we find that further analyses on the productivity effects of workplace organization need to take into account the complementarity between workplace organization and input factors as well as the simultaneity between organizational change and productivity.

6 Conclusions

This paper studies the effects of workplace organization on labor productivity by using simultaneous equations techniques. We apply a general and flexible framework to analyze the productivity effects of organizational change. A firm's decision whether or not to reorganize workplaces is assumed to depend upon the productivity differential with and without workplace reorganization net associated reorganization costs. An endogenous switching regression model is applied to 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.

Our estimates show that workplace reorganization in the form of enhanced group–work and flattening of hierarchies neither leads to significant changes in the partial output elasticities of ICT–investment, non–ICT–investment and labor nor in the returns to scale. The point estimates with respect to non–ICT–investment and labor, however, tend to be larger if workplace reorganization takes place. We do not find significant differences between the partial productivity of ICT–capital and non–ICT–capital.

Kernel density estimates of the log-labor productivity distribution, conditional on the choice whether or not to reorganize workplaces, show that workplace organizational change induces a positive and significant shift in the distribution of labor productivity for firms that reorganize workplaces. This points at strategic complementarities between the various input factors and workplace reorganization. The Kernel density estimates also do not show gains in labor productivity for those firms without organizational change compared to the hypothetical case that they reorganized workplaces, indicating that firms on average take the "right decision" regarding workplace reorganization.

We derive two organizational implications from our results. First, our finding that strategic complementarities exist between the input factors and organizational change indicates that firms can gain even more from investments in input factors if they additionally change their workplace organization. Second, the small differences between the productivity effects of hierarchy flattening and group work reinforcement indicate that the driving force behind the productivity gains are those features that are common to the two forms of organizational changes: improvements in the flow of information and worker motivation. This in turn implies that other forms of organizational change that improve information flow and worker motivation might lead to similarly sized productivity effects — at least in the knowledge–intense and social–skill intense business–related services sector.

A straightforward extension of the present analysis is the use of panel data to study the effects of workplace reorganization on labor productivity and on labor productivity growth. The latter aspect is analyzed by Bresnahan et al. (2002) using firm level data and showing that workplace reorganization fully reveals its effects on labor productivity with a time lag. Since panel data is currently not available, this issue has to be left for future research. Moreover, more flexible production functions may be used to assess the effects of organizational change on productivity.

Figure 1: Changes in the conditional log–labor productivity distribution due to enforcement of group–work: what if firms with group–work enforcement had not undertaken organizational change?

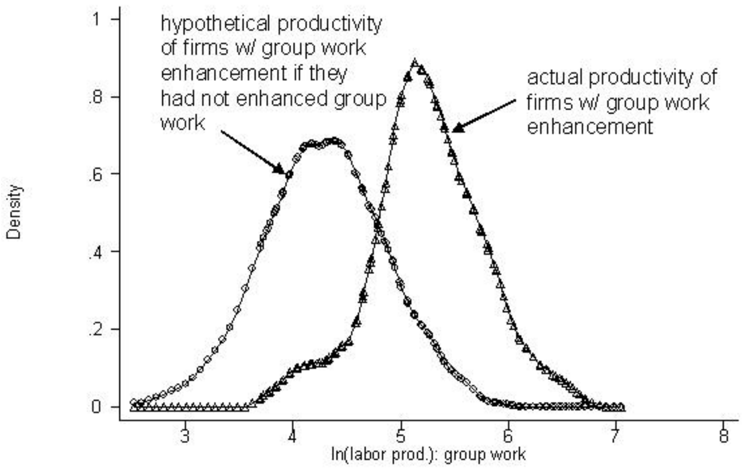

Figure 2: Changes in the conditional log–labor productivity distribution due to enforcement of group–work: what if firms without group–work enforcement had undertaken organizational change?

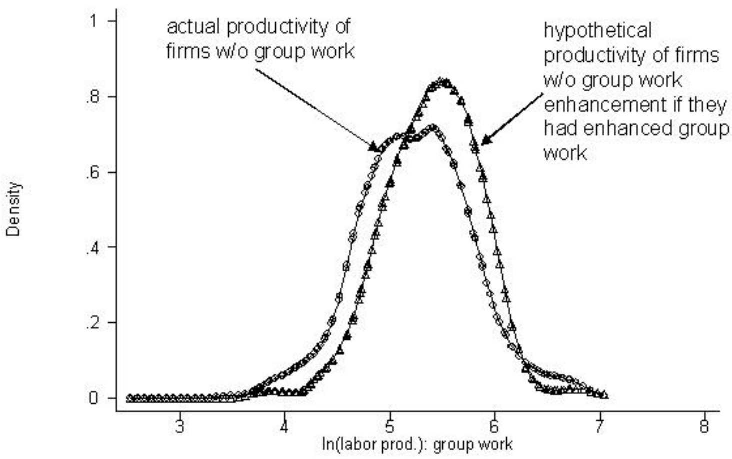

Figure 3: Changes in the conditional log–labor productivity distribution due to flattening of hierarchies: what if firms with hierarchy flattening had not undertaken organizational change?

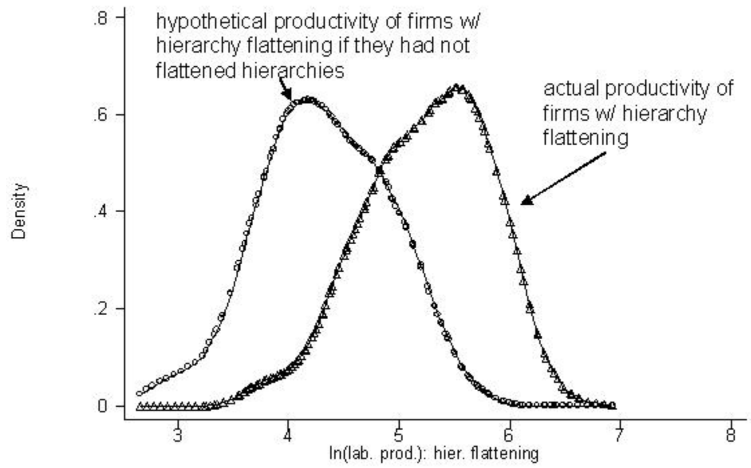

Figure 4: Changes in the conditional log–labor productivity distribution due to flattening of hierarchies: what if firms without flattening of hierarchies had undertaken organizational change?

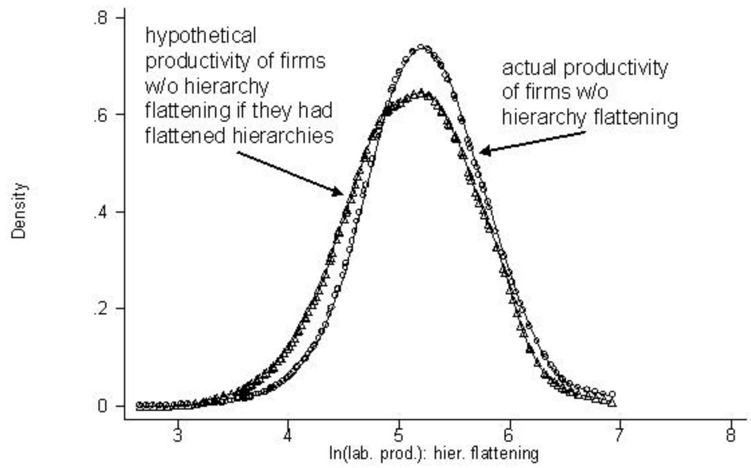

Table 1: Percentage share of firms with workplace reorganization

Type of workplace reorganization:	Firm share (in %):	# of firms
Enhancement of group–work	38.93	160
Flattening of hierarchies	27.98	115
Both	15.33	63

Table 1 displays the share and the absolute number of firms which enhanced group–work and/or flattened hierarchies. The total number of firms considered here is 411.

Table 2: Descriptive statistics

	Quantile				
	10 per cent	50 per cent	90 per cent	Mean	Std. err.
ICT–investment⋆	10	50	500	283.1	861.9
Non–ICT–investment⋆	19,6	150	2,000	1,146.6	5,225.9
# of employees	7	25	140	68.9	142.5
Output⋆	1,000	5,000	40,000	22,959.5	102,600.3
Productivity°	82.7	185.4	507.2	299.3	437.2

⋆ in 1,000 DM; ° output per worker (total sales per year in 1,000 DM).

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	0.1700***	0.0579
$ln(L)$	-0.3480***	0.0874	-0.3227***	0.1255
East Germany	-0.0042	0.1563	-0.1203	0.1703
Constant	4.9331***	0.4859	4.8325***	0.8066
ρ_1	-0.1276	0.4228	0.1245	0.4736
σ_1	0.7618***	0.0519	0.7526***	0.0698
	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	-0.0715	0.1188
Constant	5.7324***	0.3747	5.7330***	0.3900
ρ_2	-0.6840***	0.1293	-0.6661***	0.1449
σ_2	0.8403***	0.0820	0.8300***	0.0754
	Wald tests for identity of the coefficients			
	Test stat.	p–value	Test stat.	p–value
$ln(ICT)$	0.0900	0.7640	0.1610	0.6883
$ln(K)$	0.6978	0.4037	0.1935	0.6600
$ln(L)$	0.5223	0.4700	0.9914	0.3194
Returns to scale	2.0419	0.1530	1.6459	0.1995
Set of input factors	2.5682	0.4631	1.9054	0.5923
East Germany	0.6745	0.4115	0.0545	0.8154
Sector dummies	13.0698	0.1596	10.1295	0.3401
Constant	1.7102	0.1910	0.9838	0.3213
Entire specification	18.4274	0.1718	18.4337	0.1877
	Wald tests for joint significance			
	χ^2	p–value	χ^2	p–value
	Regime with organizational change			
Factor inputs	25.2564	0.0000	17.4946	0.0006
Sector dummies	9.8110	0.3660	18.9154	0.0259
Entire specification	56.1845	0.0000	55.4516	0.0000
	Regime without organizational change			
Factor inputs	40.2032	0.0000	61.0463	0.0000
Sector dummies	30.4624	0.0004	19.0040	0.0252
Entire specification	95.1554	0.0000	100.8017	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.

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	0.0652
$ln(K)$	-0.0190	0.0581	0.0054	0.0656
$ln(L)$	0.0765	0.0763	0.1801***	0.0814
East Germany	0.4726***	0.1916	0.4323	0.1689
Exporting firm	0.3181***	0.1420	0.0628	0.1548
Foreign competition	0.3898***	0.1417	0.4614***	0.1417
Apprenticeship problem	-0.3447***	0.1361	-0.1777	0.1505
Sales balance$_{t-2}$	-3.0770*	2.3208	–	–
Sales balance$_{t-3}$	2.8707	2.4112	–	–
Constant	-0.1106	0.4815	-1.5689***	0.5205
	Wald tests for joint significancy			
	χ^2	p–value	χ^2	p–value
Factor inputs	2.5596	0.4646	10.9846	0.0118
Sector dummies	9.4173	0.4001	11.9677	0.2152
Sales balances	1.7584	0.4151	–	–
Entire set of identifiers	24.4614	0.0002	14.6839	0.0021
Entire sel. eq.	49.8462	0.0001	52.6885	0.0000
	Wald tests for joint significance: entire switching regression model			
Correlation coefficients	27.9659	0.0000	21.4703	0.0000
Entire switching regression	207.2210	0.0000	217.3362	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.

Table 5: Tests for significant differences in conditional log–labor productivity distributions

	Firms considered	Mean difference	p–value mean difference > 0
Enhancement of group–work			
Figure 1	w/ change	0.9569	0.0038
Figure 2	w/o change	0.1540	0.3264
Flattening of hierarchies			
Figure 3	w/ change	0.9171	0.0017
Figure 4	w/o change	-0.1374	0.3305

Table 5 displays results of tests for positive differences in the means of kernel estimations of conditional log–labor productivity between the productivity regimes.

Table 6: Wald tests for the identity of the partial elasticities of ICT and non–ICT–investment

	Test stat.	p–value
Group work		
W/ organizational change	0.1682	0.6817
W/o organizational change	0.2796	0.5970
Flattening of hierachies		
W/ organizational change	0.0154	0.9012
W/o organizational change	0.3826	0.5362

Table 6 presents the results of Wald test for identity of the partial elasticities of ICT and non–ICT–investment.

Table 7: Means, medians and standard errors of the estimated unconditional log–labor productivity

	Mean	**Median**	**Std. err.**
Group work			
w/ workplace reorganization	5.3433	5.3318	0.4785
w/o workplace reorganization	4.8752	4.8521	0.5659
Flattening of hierarchies			
w/ workplace reorganization	5.1512	5.1685	0.5426
w/o workplace reorganization	4.9911	4.9761	0.5352

Table 7 displays means, medians and standard errors of log labor productivity estimated on the basis of the switching regression model.

7 Appendix

Table A: Descriptive Statistics of the ICT-investment as a share of total investment across industries

	Mean	Std. err.	Obs
consumer goods	0.1373	0.2194	131
chemical industry	0.1147	0.1521	75
other basic goods	0.0801	0.1274	141
mechanical engineering	0.1241	0.1339	153
electrical engineering	0.1622	0.1934	112
medical, precision and optical instruments	0.1546	0.1709	113
motor manufacturing industry	0.1298	0.1465	112
wholesale trade	0.1385	0.1420	89
retail trade	0.1821	0.2256	92
transport and post	0.0973	0.1796	110
financial intermediation	0.2799	0.2630	79
computer and telecommunication services	0.3488	0.3000	112
technical service industries	0.2676	0.2488	111
other business services	0.1884	0.2273	94

Table A displays descriptive statistics based on a ZEW–survey in the year 2000. The data is described by Bertschek and Fryges (2002).

Estimating productivity differentials

A firm's productivity in the case of organizational change is compared to the hypothetical productivity that this firm would achieve if it did not reorganize workplaces and vice versa, the productivity of a firm without organizational change is compared to the hypothetical case that this firm did reorganize workplaces. Hence, in order to control for the firms' selection decision, the productivity is calculated conditional on the firm's choice whether or not to engage in organizational changes. Otherwise, the estimation results might be biased (see for instance Greene (2000, pp.926–934) for further details). The estimated productivity differential can then be calculated as follows:

$$PD_{ioc} = E[ln(y_i/L_i)_{oc}|X_{ioc}, ORG = 1] \tag{13}$$

$$- E[ln(y_i/L_i)_{noc}|X_{ioc}, ORG = 1]$$

$$= X_{ioc}(\delta_{oc} - \delta_{noc}) + (\theta_{oc} - \theta_{noc})\lambda_{ioc}, \tag{14}$$

where the first term of equation (13) represents the expected labor productivity for firms with organizational change, the second term is the expected labor productivity for firms with organizational change (ORG=1) in the hypothetical case that they had not chosen organizational change. $\lambda_{ioc} = \phi(Z_i\pi)/\Phi(Z_i\pi)$ and $\theta_{oc} = \rho_{oc}\sigma_{oc}$, $\theta_{noc} = \rho_{noc}\sigma_{noc}$ where $\phi(\cdot)$ and $\Phi(\cdot)$ represent the density and the distribution function of the standard normal distribution. The productivity differentials are visualized by Figures 1 to 4. The term $X_{ioc}(\delta_{oc} - \delta_{noc})$ represents the unconditional expected value of the log labor productivity, depending on the observable variables. The second term $(\theta_{oc} - \theta_{noc})\lambda_{ioc}$ represents the impact of the firms' selection into organizational change where λ_{ioc} is the Mill's ratio. For the opposite case, $\lambda_{ioc} = -\phi(Z_i\pi)/(1 - \Phi(Z_i\pi))$.

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