Productivity Effects of Organizational Change: Microeconometric Evidence

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Appendix A: The Maximum Likelihood function

In this Appendix we derive and describe the Full Information Maximum Likelihood estimator we used to estimate our endogenous switching regression model:

The contribution of the ith observation to the likelihood function associated with such a system of equations is

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

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:

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

and likewise:

$$ORG_{|ln(\frac{y_i}{L_i})_{noc}} \sim N\Big(-\boldsymbol{Z_i\Pi} - \frac{\sigma_{ORG,ln(\frac{y_i}{L_i})_{noc}}}{\sigma^2_{ln(\frac{y_i}{L_i})_{noc}}}\big(ln(\tfrac{y_i}{L_i})_{noc} - \boldsymbol{X_i\delta_{noc}}\big); \sigma^2_{ORG}(1-\rho^2_{ORG,ln(\frac{y_i}{L_i})_{noc}})\Big). \tag{3}$$

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:[1]

[1]The GAUSS code that we used for the estimation of the model is downloadable from the Internet at http://www.ulrichkaiser.com/papers/orga.html. 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.

$$ln\Phi\left(\frac{\boldsymbol{Z_i\Pi}+(ln(\frac{y_i}{L_i})_{oc}-\boldsymbol{X_i\delta_{oc}})\rho_{oc}/\sigma_{\frac{y_i}{L_i}oc}}{\sqrt{1-\rho_{oc}^2}}\right)-\frac{1}{2}\left(\frac{ln(\frac{y_i}{L_i})_{oc}-\boldsymbol{X_i\delta_{oc}}}{\sigma_{ln(\frac{y_i}{L_i})_{oc}}}\right)^2-ln(\sqrt{2\Pi}\sigma_{ln(\frac{y_i}{L_i})_{oc}}) \text{ if } ORG=1$$

and (4)

$$ln\Phi\left(\frac{-\boldsymbol{Z_i\Pi}-(ln(\frac{y_i}{L_i})_{noc})-\boldsymbol{X_i\delta_{noc}})\rho_{noc}/\sigma_{\frac{y_i}{L_i}noc}}{\sqrt{1-\rho_{noc}^2}}\right)-\frac{1}{2}\left(\frac{ln(\frac{y_i}{L_i})_{noc}-\boldsymbol{X_i\delta_{noc}}}{\sigma_{ln(\frac{y_i}{L_i})_{noc}}}\right)^2-ln(\sqrt{2\Pi}\sigma_{ln(\frac{y_i}{L_i})_{noc}}) \text{ if } ORG=0.$$

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.

Appendix B: Descriptive statistics of key variables

In this Appendix we describe in some detail the key variables that are involved in our estimations:

Table B 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).[1] 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.[2] 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

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

[2] See also Table E in Appendix E on the Internet.

waste and refuse disposal.

Table B: 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$^{\circ}$	82.7	185.4	507.2	299.3	437.2

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

References

Janz, N. and Licht, G. (1999). *Innovationsaktivitäten der deutschen Wirtschaft (Innovation activities in the German economy)*, Vol. 41, Nomos Verlag.

Appendix C: Estimation results for separation equations

In this Appendix we display and discuss the estimation results corresponding to the separation equations:

An important result of the two reduced form separation equations, as displayed in Table D, 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.[1]

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

[1]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.

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 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 (**?**, 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 C: 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 D displays estimation results for the selection equations of the endogenous switching regression model. A total of 411 observations was involved in the estimations.

Appendix D: Estimating productivity differentials

This Appendix describes the estimation of productivity differentials for firms with and without workplace reorganization:

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 **?** for further details). The estimated productivity differential can then be calculated as follows:

$$\begin{aligned} PD_{ioc} &= E[ln(y_i/L_i)_{oc}|X_{ioc}, ORG = 1] && (1) \\ &- E[ln(y_i/L_i)_{noc}|X_{ioc}, ORG = 1] \\ &= X_{ioc}(\delta_{oc} - \delta_{noc}) + (\theta_{oc} - \theta_{noc})\lambda_{ioc}, && (2) \end{aligned}$$

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 dif-

ferentials 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, $\lambda_{ioc} = -\phi(Z_i\pi)/(1 - \Phi(Z_i\pi))$.

Appendix E: Caveats

In this Appendix we discuss in some length the caveats involved with our study:

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 forms 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 below.[1] 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

[1]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.

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 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 these 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, Brynjolfsson and Hitt (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.

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

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