Technological change and employer-provided training: evidence from German establishments

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Abstract

There is a wide range of theoretical and empirical analyses suggesting that technological change has increased the demand for skills. Since training is a mechanism to upgrade workers' skills, it would be expected that technical progress strengthens the importance of training on account of the requirement for skills to complement new technology. However, the relationship between technical progress and firms' (employer-funded) continuous training has been little investigated. In our research we address the theoretical gap by building upon existing models from the skill-biased technological change and training literatures. This theoretical platform supports a maintained hypothesis of a positive relationship between training and technological change, which we investigate empirically for Germany using data from the IAB establishment panel. Our empirical findings indicate that in Germany a greater share of workers undergo further/continuing training in establishments subject to technological change. An important issue we raise in our empirical analysis is the possibility of endogeneity/simultaneity between training and technological change.

Key words: Further training; Technological change; Skills.

Acknowledgments

The authors thank the Institute for Employment Research (IAB) for data provision and support. The IAB bears no responsibility for the authors' analysis and interpretation of the data.

Introduction

There is a wide range of models explaining firms' training behaviour. This literature has identified several factors that induce and discourage firms' provision of training. Wage compression and low labour turnover have been considered as the main factors inducing firms to provide training (Katz and Zidermann, 1990; Stevens, 1994; Acemoglu and Pischke, 1998; Acemoglu and Pischke, 1999a and 1999b; and Lazear, 2003). Information asymmetry related to training received by workers and/or about the ability of workers has been considered to lead to

imperfections in the labour market, compressing the wage structure and hence inducing firms to train (Leuven, 2005). Acemoglu and Pischke (1999a and 1999b) explain that certain labour market frictions and institutions may compress the wage structure. These include mobility costs, asymmetric information, firm-specific human capital, efficiency wages and wage floors (e.g. minimum wages). The influence of unions on firms' training decisions is complex and depends on whether a union's effect on training is indirect (through altering the wage structure as in Acemoglu and Pischke, 1999b) or direct (through the negotiation of training availability) (Bassanini et al., 2007). Unions may use training as an instrument to ensure that their members receive higher wages and greater job security. Therefore, this rationale predicts that unionised firms will provide more training. Unions may also be associated with increased training, by improving workers' morale and reducing labour turnover. If firms provide training to workers whose productivity is below the minimum wage, the increased productivity due to training of those workers who already receive the minimum wage does not need to be reflected in increased wages, in which case the benefit of increased productivity accrues to the employer. In this case it is beneficial for firms to train workers (Acemoglu and Pischke, 1999b and Bassanini et al., 2007). According to human capital theory, longer employment relationships, extending the period over which firms can recoup benefits from trained workers, improves firms' incentives to pay for training (Arulampalam and Booth, 1998 and Arulampalam et al., 2004).

There are a number of empirical analyses suggesting that technological change has increased the demand for skills. For example, Abowd et al. (2007) found a strong positive empirical relationship between advanced technology and skill in a cross-sectional analysis of US businesses in services, wholesale and retail trade sectors. Since continuing training is a mechanism to upgrade workers' skills, it would be expected that technical progress strengthens the importance of training on account of the requirement for additional skills to complement new technology. In common with most recent studies, we include in our notion of technological change not just changes in production methods and the capital intensity of production, but also changes in organisation and work practices which result in higher productivity. In our empirical work we separate these two types of technological change. Even though there are a wide range of studies investigating the determinants of training and the hypothesis of skill-biased-technological change, the relationship between technological change and training has not previously been directly examined in theoretical and empirical analyses. In this study we fill the former gap by building

upon Acemoglu's model (2003) from the skill-biased technological change and Snower's model (1996) from the training literature. This theoretical platform supports a maintained hypothesis of a positive relationship between training and technological change, which we investigate empirically for Germany using data from the IAB establishment panel. In this study training refers to further training financed by employers, and for which employees are released from work in order to participate in establishment or external training measures or that the company bear the costs of external training measures. Our findings indicate that in Germany there is a positive relationship between technological change and further training. An important issue we raise in our empirical analysis, not previously acknowledged, is the possibility of endogeneity/simultaneity between training provision and technological change. This implies not only that technological change induces more training but also that training may increase the probability of firms undertaking technological change.

The structure of this paper is as follows. In Section 2, we present a brief summary of the relevant training literature and present our model linking technological change and continuing training. Section 3 provides a review of previous empirical analyses of employer-provided training in Germany. Section 4 provides a brief introduction to the IAB dataset, including descriptive statistics, and sets out our empirical model. In Section 5 we outline the econometric approach of our empirical analyses, analyse the determinants of training incidence and intensity, consider the issue of endogeneity and present robustness checks for our results. Section 6 concludes.

Technological change and employer-provided training: a theoretical framework

The review of the existing training literature provided in the section above indicates that this literature focuses on determinants that enable the firm to appropriate benefits from training investments rather than developing a systematic analysis of the demand side for training, i.e. what drives firms to provide training. An exception is a model developed by Snower (1996). Although this model considers workers' decisions to undertake and finance training, it incorporates the availability of skilled jobs as the main factor determining firms' training decisions. Nevertheless, this model assumes that the demand for skills/training is static and hence does not explain changes in skills/training. To formulate the link between technological change and training we

extend Acemoglu's model (2003) that examines firms' technology choice decisions, and then integrate determinants from the general training literature and Snower's model. Skill-biased technological change predicts that technological change is more profitable with skilled workers, and therefore increases the demand for those workers. Yet none of the studies on skill-biased technological change considers the influence of these changes on the required skill intensity of workers. Since continuing training enhances the skill intensity of workers rather than the supply of skilled workers, we hypothesise that to generate the whole potential benefits from new technology workforce skill intensity needs to be increased, which is attained through continuing training. The model is as follows.

In the first period the firm operates with the existing technology (A^{pre}, pre indicating the period before the technology shock) and initial human capital denoted by h_0, which borrowing from Dearden et al., (2006) is $h_0=N_u+\gamma N_s$: N_s represents the number of skilled workers; N_u the number of unskilled workers; and γ is a parameter greater than unity, which allows skilled workers to be more productive than unskilled workers. The production function of the firm in the first period is given by:

$$A^{pre} h_0 \ where \ h_0 > 0 \qquad \textbf{(1)}$$

In the second period there is a technology shock and the firm can choose either to continue using the existing technology with the existing skill level of the workforce or to adopt the new technology (A^{post}) at a cost (k) and produce more at a lower per output cost. However, to reap benefits from the new technology the skill intensity of workers in the second period needs to be enhanced from level h_0 *to* h_2. The additional skill intensity is obtained through continuing training, which imposes training costs on the firm. To clarify, $h_2=h_0+h_1$: where h_2 is the second period human capital stock; h_0 is the initial human capital; and h_1 is the additional human capital imparted to workers by on-the-job training when the new technology is introduced. If the firm introduces the new technology it produces:

$$(1+\alpha) A^{post} h_2 \qquad \textbf{(2)}$$

In equation (2) through the productivity parameter ($\alpha>0$) new technologies induce greater production. As noted, for the new technology to be profitable the firm has to provide increased continuing training. Whereas in Snower's model rising marginal training costs originated from heterogeneity in the ability of workers, in our setup the rising marginal training costs are assumed

to rise due to the opportunity costs to the firm of financing training (eh_1^{ε}; where constant (e) stands for direct training costs and (ε) the exponent depicts the increasing costs of training reflecting the opportunity costs that the firm faces when it funds further increases in the skill intensity of workers).

The technology adoption decision of the firm depends on the expected net benefit from the new technology: i.e. the rent taking into account the additional skill intensity, the technology cost (k) and training costs for incremental skill intensity (h_1). The condition for firms to adopt the new technology is given by:

$$(1-\beta)\alpha A^{post} h_1 > k + eh_1^{\varepsilon} \qquad \textbf{(3)}$$

where β is the workers' bargaining power (1- β is the firm's bargaining power in the wage determination process and $0 \geq \beta \leq 1$). Equation (3) can be interpreted as follows: firms will incur technology costs and increase the training of their workers whenever the surplus appropriated by firms is greater than the combined technology adoption and training costs. Expected net benefits from new technologies and training depend on: technology and training costs ($k + eh_1^{\varepsilon}$); the firm's bargaining power $(1-\beta)$; and the productivity gain from new technologies and training $(\alpha A^{post} h_1)$. However, in the model there are two limitations on the skill intensity of the workforce. The first one originates from the rising marginal costs of training which, for a given level of technology and firm's bargaining power, limits the increase of skill intensity. The second limitation is related to firms' bargaining power, which should be sufficient to enable firms to generate positive returns from investment in technical progress and training, adjusted for risk.

From this model we hypothesise that firms undertaking technological change are more likely to train. Moreover, complementarity between skills and new technologies suggests the potential for a two-way relationship between new technologies and training. This implies that not only does the training decision of the firm depend upon its decision to update its technology, but also that the technology adoption decision may be influenced by its training provision. Accordingly, our empirical strategy considers the potential endogeneity of technological change.

Determinants of employer-provided training: evidence from previous studies

In this section, we briefly discuss the existing evidence on the determinants of further training in Germany. With respect to technological change Zwick (2002 and 2006) found that establishments operating with new technologies, which invested in ICT and operate with team working, are both more likely to train and to train a greater share of workers. Another positive influence on training provision is the share of apprentices at the establishment (Zwick 2002 and 2006). It is found that when establishments consider training as a high priority reaction to skill shortages, and when high qualifications are needed, establishments are more likely to train and also train a greater share of their workforce (Zwick 2002 and 2006). The greater the share of high-skilled workers the greater the incidence and the share of workers that receive further training (Brussig and Leber, 2006). In establishments where wages are collectively set, the share of workers that received training is found to be greater (Zwick, 2002). Brussig and Leber (2006) found that firms facing difficulties in filling skilled vacancies provide more training; and, finally less training is found to be provided in establishments that employ a higher share of employees with fixed-term contracts, females and old workers (Pischke, 2001). Although Zwick (2002 and 2006) has empirically examined the influence of technological change on further training, the value our study brings is that Zwick uses a cross-section for one year only, whereas our investigation uses panel analysis to exploit the full potential of the IAB's longitudinal data. Additionally in our empirical investigation we add two more technological change measures i.e. a variable indicating whether the establishment foresees investments for the coming year and the measure for investment volume of the establishment in the prior year.

Data, empirical model and descriptive statistics

In this paper for empirical examination data are extracted from the Institute for Employment Research (IAB) establishment panel, the largest firm-level dataset in Germany. The basis for this dataset is the employment statistics register of the Federal Employment Services (FDZ). The unit of survey is the establishment, not the company as a legal and commercial aggregate. By

establishment is meant a unit in which the activities of a company, that is, the production of goods or services, are actually carried out. The establishments are selected from a sample of all German establishments that employ at least one employee covered by the social security system. For explanation of the sampling procedure, see Kölling (2000).

The survey started in 1993 with data from West Germany only; and since 1996 has incorporated data from the East as well. In 1993, the panel started with 4,265 establishments from the West; and added 4,313 from the East in 1996, building to 10,104 and 5,585 in the West and East respectively by 2004. The survey is held in the middle of each year. Some questions, such as average employment during one year, output, and profit situation, are therefore asked retrospectively in the following wave. The IAB dataset is particularly suited to carrying out separate analysis for West and East Germany, which is appropriate as the labour market conditions (unemployment rate, union presence, wage setting system, organisation of establishments, the quality and age structure of the labour force, etc.) in the two parts of the country differ substantially (Beckmann, 2002; Zwick 2002 and 2006).

The IAB dataset contains variables for the sampling weights for each year (cross section weights) and panel weights for different combinations of years (for instance 93-2000, 93-2001, etc.). The application of the panel sampling weights in the IAB data requires a balanced panel. However, here we are constrained by an unbalanced panel. Hence, we can apply only cross section weights. For this reason, we obtained unweighted statistics for the whole panel and also statistics for each year with the corresponding cross section weight. We restrict the sample to the private sector only. This is because even though the public sector may be substantially involved in workplace training their motivation presumably differs from that of profit-maximising establishments.

In this study we use two measures for further training, i.e. the incidence and intensity of training. In order to avoid picking training for other than productivity enhancing purposes we centrally focus upon the training intensity. The training *incidence* measure is defined from the question:

Did your enterprise pay for further training in the first half of the year? i.e. were employees released from work in order to participate in establishment or external training measures or did your company bear the costs of external training measures?[1].

A second question enables us to construct a measure of training *intensity*. Employers can report either the number of employees participating in further training or the number of training events. Whilst the question about the training incidence appears almost in all years, the question about the training intensity was asked only in 1998, 1999, 2001, and 2003. Using data from the whole panel (1993-2003) 59 and 63 percent of establishments reported the provision of further training in East and West Germany respectively. When data are weighted for each year, the proportion of establishments reporting training increased from 37 percent in 1997 to 41 percent in 2003 (see Table 2: referring to those years since data for East Germany subsequently became available).

Starting from 1998, measures for the training intensity are available for 1999, 2001 and 2003, which are covered under a shorter panel constructed to examine training intensity. The measure for training intensity is derived from the question about the number of employees trained rather than the number of training events. The first rationale for using the former measure is that across the three years covered under the panel, around 80 percent of establishments responded to the former question rather than the question concerning the number of cases. Second, from the number of training events we cannot judge training participation, since a large number of events could imply both that many workers were trained with fewer courses and that few workers were trained but underwent many training courses. The variable we choose for our empirical analysis has also been used as a measure of training intensity in previous studies using the IAB dataset (Zwick, 2002 and 2006). When the dependent variable is constructed, establishments that have reported the number of training events are considered as missing observations, since we know that training was provided but do not know how many employees were trained.

From the three years comprising the short panel, and restricting the sample to the private sector and conditioning upon training provision, unweighted statistics indicate that the average number of workers that have undergone training in the first half of the year in establishments in West Germany is 56; and 30 in the East (the median is 8 and 6 respectively). Notice that the difference

[1] Translated by IZA (see http://metadata.iza.org/home.php)

between the two regions with regard to the number of workers that have received further training in the last six months is statistically significant at the one-percent level of significance. However, when we apply sampling weights for each year individually, the average number of trained workers is significantly lower for both West and East (7, 6, 7 and 6, 5, 7 employees for West and East Germany for 1999, 2001 and 2003 respectively). The large difference between the mean and the median results arises from the large number of small establishments in the IAB sample, which train fewer workers compared to large establishments. With regard to the percentage of trained workers, it declined from 33 to 27 percent between 1999 and 2001 but was followed by an increase to 38 percent in 2003.

Empirical analysis of training incidence includes two measures of technological change, whereas four indicators are used when examining the intensity of training. The first technology measure is constructed using the question about the technical state of the technology used in the establishment, ranging between one and five, where one corresponds to working with modern technologies and five means that the technologies in use are obsolete. This ordinal variable is replaced by three dummy variables representing the values at the extremes and in the middle (i.e., new/modern technologies, the technological norm and old technologies). The norm is used as the benchmark category. The second proxy is the firm's investments in the previous year measured in million EUROs. In the short panel these two measures are supplemented by two additional variables. A dichotomous variable is constructed signifying whether an establishment has, in the previous year, invested in information and communication technology (ICT). The last measure for technological change is derived from the question about whether investments are foreseen for the current year.

New management practices such as team working and quality circles intend to enhance employees' participation in the design of work processes and the sharing of task-specific knowledge as to how those processes can be improved and productivity increased (Kersley et al., 2005). Consequently, these practices require skilled workers and, accordingly, may induce more training. To measure whether new management practices increase the necessity for training we include a dummy variable for the presence of team working at the establishment. Data reveal that around 14 and 10 percent of establishments in the West and East respectively operate team working.

In the model, we assess the influence of the presence of works councils (codetermination) and unions on training incidence and intensity, anticipating a positive association with further training provision. The rationale for expecting a positive influence of unions on training provision is based on the following explanations: labour unions may directly negotiate better training opportunities for workers; unions might contribute in providing constraints on the mobility of trained workers, and therefore may have an important influence on firms' willingness to invest in training (Gerlach and Jirjahn, 2001, Beckmann, 2002, and Zwick, 2002 and 2006); and since, legally, union wages act as a minimum wage, hence, compressing the wage structure, unions enable firms to appropriate benefits from increased productivity of workers with training which, accordingly, encourages establishments to provide training and also train more. According to Gerlach and Jirjahn (2001) works councils promote training by addressing the poaching problem. The explanation for this is that in Germany works councils promoting opportunities related to internal labour markets reduce the mobility of workers between establishments, thereby ensuring a longer period over which firms can obtain benefits from trained workers. Representing the interests of workers employed in the firm, works councils foster training for insiders instead of hiring workers from the external labour market. Moreover, the wage structure of internal labour markets, constrains management's possibilities to use wage strategies to poach workers from other establishments (Gerlach and Jirjahn, 2001 p.146)

We include a variable measuring the proportion of workers who are employed on (short-term) fixed-duration contracts. Faced with increased demand for skill, besides training as a mechanism to obtain those, an alternative strategy that establishments may use is to use already trained workers and temporary and agency employees from the market. In addition, workers employed under these contracts enable the firm to raise flexibility, to extend probation periods for screening purposes, or to avoid high firing costs. These explanations suggest a negative relationship between use of temporary employees and training.

In our analysis we include a variable to measure the impact of profitability of establishments on training intensity. This is measured by three dummy variables indicating whether or not establishments assess their profitability as good, satisfactory or poor. It can be assumed that establishments are more engaged in training when they are content with their economic situation,

because such firms may be more able to bear the cost of training. However, we can also argue that firms with good profitability may not have incentives to provide training, being satisfied with their profitability. This discussion indicates that a priori we are not certain about the expected sign of this variable. Similarly, we possess no theoretical explanation for the expected influence of the business volume on training provision. First, because even if this measure represents turnover it is the value added that we would expect to exert an influence on training, for which business volume is a poor measure. Second, we cannot predict the relationship between training and business volume.

In our empirical model we also include: the number of employees; the proportion of apprentices at the establishment; the share of part-time and unskilled workers; and seven sector dummies. The potential number of employees who participate in training may increase with the size of the firm. Economies of scale lower the unit costs of training. Further, larger establishments are more likely to establish internal labour markets which, as noted above, may lower labour turnover and hence encourage firms to train. With increased opportunities for promotion, labour turnover may be reduced raising the probability of establishments to benefit longer from training activities. The proportion of apprentices might influence training in two directions. First, investment in apprenticeship training may substitute for further training; and, second, further training and apprenticeship training may be complements. The latter hypothesis can be supported with the explanation that technological change contributes to obsolescence of initial training, which then may strengthen the necessity for continuing training.

Econometric approach, findings and discussion

Using the IAB dataset, we estimate both the incidence and intensity of training. To avoid the case that our measure of training incidence may pick up training for other than productivity-enhancing reasons, such as for health and safety, we devote particular attention to the training intensity (i.e., the number of workers trained in the first half of the year).

The decision of establishments to pay for training of their employees is modelled in a binary probit model and that random effects probit. To investigate the training intensity, a dependent variable is derived from the number of workers trained in the last six months. Accordingly, the

dependent variable for training intensity takes on the value zero for a substantial proportion of observations, while it is a continuous random variable over strictly positive values for establishments that have provided training to their workers. This defines a 'corner solution model', which requires tobit estimation (Wooldridge, 2002; Greene, 2003). Since our data are censored at the lower/left end at zero values, we apply a left censored random effects tobit model, which allows us to draw inferences with respect to the population.

In the next section, we present empirical findings for both training incidence and training intensity (number/share of workers that received training in the previous six months).

Empirical findings

Training incidence

In this section, empirical findings for the determinants of training incidence - i.e. the probability that establishments provided further training in the previous six months obtained from the random effects probit- are presented (Table 1). On an irregular basis different additional topics are sampled in consecutive waves of the IAB survey, implying that some variables considered as determinants of training are available in only some waves. In order to make the best use of the panel data, and as a robustness check, we estimate five different specifications by including variables in the model as they enter the panel survey and, from 1996, estimate models separately for West and East Germany. In Table 1, we provide empirical findings for the training incidence.

Table 1: Empirical findings: training incidence, probit estimates, marginal effects

Marginal effects, probit estimates	Specification 1			Specification 2			Specification 3			Specification 4						Specification 5					
	West			West			West			4. West			4.1 East			5. West			5.1 East		
Explanatory variables	**dy/dx**	**P>|t|**		**dy/dx**	**P>|t|**		**dy/dx**	**P>|t|**		**dy/dx**	**P>|t|**		**dy/dx**	**P>|t|**		**dy/dx**	**P>|t|**		**dy/dx**	**P>|t|**	
Number employees	0.002	0.000	***	0.003	0.000	***	0.003	0.000	***	0.003	0.000	***	0.002	0.000	***	0.003	0.000	***	0.004	0.000	***
Proportion apprentices	1.93	0.000	***	1.73	0.000	***	1.63	0.000	***	1.63	0.000	***	0.65	0.000	***	1.81	0.000	***	0.75	0.000	***
Proportion unskilled	-0.70	0.000	***	-0.84	0.000	***	-0.86	0.000	***	-0.85	0.000	***	-0.56	0.000	***	-0.78	0.000	***	-0.67	0.000	***
Proportion part time	-0.29	0.000	***	-0.30	0.000	***	-0.24	0.001	***	-0.26	0.001	***	-0.16	0.087		-0.36	0.000	***	-0.25	0.015	**
Proportion fixed term contracts	0.73	0.000	***	0.56	0.000	***	0.55	0.000	***	0.60	0.000	***	0.25	0.030	**	0.45	0.009	**	0.17	0.232	
Business volume	0.003	0.000	***	0.004	0.000	***	0.004	0.000	***	0.004	0.000	***	0.014	0.000	***	0.005	0.000	***	0.008	0.000	***
Investment in EURO	-0.002	0.711		-0.003	0.588		-0.004	0.493		-0.005	0.381		0.058	0.000	***	-0.005	0.420		0.061	0.001	***
New technology	0.38	0.000	***	0.38	0.000	***	0.36	0.000	***	0.38	0.000	***	0.36	0.000	***	0.38	0.000	***	0.35	0.000	***
Old technology	-0.24	0.000	***	-0.23	0.001	***	-0.21	0.007	***	-0.23	0.004	***	-0.32	0.000	***	-0.23	0.005	***	-0.38	0.000	***
Work councils	1.29	0.000	***	1.02	0.000	***	1.00	0.000	***	0.96	0.000	***	0.96	0.000	***	0.90	0.000	***	0.79	0.000	***
Collective wage agreements				0.28	0.000	***	0.26	0.000	***	0.24	0.000	***	0.33	0.000	***	0.20	0.000	***	0.30	0.000	***
Team working							0.65	0.000	***	0.68	0.000	***	0.56	0.000	***	0.67	0.000	***	0.56	0.000	***
Established before 1990										0.09	0.020	**	-0.13	0.001	***	0.06	0.140		-0.17	0.000	***
Good profitability																0.18	0.000	***	0.09	0.028	***
Poor profitability																-0.01	0.790		-0.14	0.001	***
West Germany																					
Agriculture	-0.41	0.001	***	-0.28	0.023	**	-0.27	0.040	**	-0.26	0.045	**	0.05	0.670		-0.32	0.018	**	0.06	0.614	
Mining	0.34	0.024	**	0.36	0.025	**	0.37	0.031	**	0.32	0.060	*	0.14	0.461		0.20	0.238		0.24	0.226	
Construction	-0.30	0.000	***	-0.33	0.000	***	-0.32	0.000	***	-0.29	0.000	***	-0.33	0.000	***	-0.26	0.000	***	-0.29	0.000	***
Trade	0.15	0.004	***	0.19	0.001	***	0.18	0.002	***	0.18	0.001	***	0.26	0.000	***	0.21	0.000	***	0.31	0.000	***
Communication	-0.17	0.037	**	-0.13	0.140		-0.15	0.093		-0.12	0.157		-0.16	0.202		-0.11	0.195		-0.17	0.172	
Finance	0.87	0.000	***	0.89	0.000	***	0.88	0.000	***	0.86	0.000	***	0.05	0.858	***	0.84	0.000	***	0.24	0.352	
Services	0.51	0.000	***	0.60	0.000	***	0.59	0.000	***	0.58	0.000	***	0.44	0.000	***	0.48	0.000	***	0.33	0.000	***
Number of observations	**26,473**			**24,090**			**21,825**			**19,368**			**15,504**			**17,439**			**13,631**		

Note: Highlighted when differences between East and West Germany found; *, ** and ***, significant at 10,5 and 1% level of significance.

Regarding the influence of technological change on training incidence, our empirical findings across five specifications set out in Table 1 suggest that investment volume in the previous year has no significant influence on the probability of West German establishments providing further training, whereas there is a positive influence in all specifications for the Eastern establishments. However, regardless of specification, our findings indicate that, compared to establishments operating at the technological norm, establishments operating with new technologies are more likely to train whereas those with old technologies are less likely to train.

Considering the impact of new management practices, as expected we find that establishments with team working are more likely to be engaged in further training. Further training is more likely in larger establishments and in those with larger business volume. It is found that the greater the share of apprentices, the greater the willingness of establishments to provide further training. Our observation that fixed-term contracted employees can be an alternative strategy to training, and hence have a negative influence on the provision of further training, is not supported. The explanation for the positive influence may be that employing a greater share of workers under fixed term contracts may indicate that skilled workers are demanded in those establishments and therefore establishments will train to meet the demand for skilled workers.

Our findings suggest that low-skilled workers attract less training, which is consistent with higher expected training costs for these workers and, hence, less incentives for firms to train. As expected, the greater the share of part-time workers the less likely is the establishment to train, because of the shorter time span over which establishments would recoup benefits from their training investment. Additionally, if a large part of the workforce works part-time, there will be fewer hours over which to distribute any fixed training costs. As predicted, establishments with work councils and unionised ones are more likely to train. In our regression analyses we included a variable for whether an establishment was established before the 1990s, which is expected to be important for East Germany since establishments there operated under a different system and with old technologies. As anticipated, we find that Eastern establishments founded before the 1990s were less likely to provide further training, while no such influence was found in Western Germany. Establishments that considered their profitability as being good were found to be more

likely to train workers in both regions. However, whereas poor profitability in East Germany deterred training, no such influence was apparent in western establishments. As for the sector dummies, our findings indicate that, across all specifications, when compared with manufacturing, establishments belonging to the trade, finance and service sectors were more inclined to train. In the following section we report and discuss our empirical findings for training intensity.

Training intensity/number of trained workers

Data set out in Table 2 indicate that the average number of workers who received training in the first half of the year declined from 56 in 1999 to 43 in 2003. A similar pattern can be noted in the number of training events reported. As for the percentage of workers being trained, the proportion declined from 1999 to 2001 but then increased from 27 to 38 percent from 2001 to 2003, a similar pattern to the median number of trained employees.

Table 2: The number of trained employees, training events (private sector; training establishments; unweighted)

	Number of trained workers		Number of events		Percentage of trained workers	
	Mean	**Median**	**Mean**	**Median**	**Mean**	**Median**
1999	56	9	304	50	33	24
2001	42	6	300	47	27	18
2003	43	8	280	41	38	29
Average	**45**	**7**	**294**	**45**	**33**	**24**
West	56		372		31	
East	30		137		36	
Number of observations	**18,651**		**3,823**		**18,651**	

To examine the maintained hypothesis - namely, the positive influence of technological change on training intensity - a tobit model is used. To exploit the full potential of our panel data we estimate a random-effects tobit model, which takes into account both between-establishments variation and within-establishment variation over time. Estimates for both West and East Germany indicate that the random effects, which control for time-invariant unobservable

influences on establishments' training intensity, are statistically significant. In both cases, a likelihood ratio test overwhelmingly rejected the null that the panel-level variance component is unimportant (StataCorp, 2005, p.334); and the contribution of the panel-level variance component to the overall variance – rho - is 19 percent and four percent respectively. This implies that the panel estimator is different from the pooled estimator (Wooldridge, 2002, pp.129 and 170). Accordingly, we report results obtained from the panel estimator.

Before we proceed with interpretation of our empirical findings, we first report a general check that the statistical specification of the tobit model is adequate, hence on the appropriateness of tobit estimation, we implement a procedure suggested by Greene (2003, p.776) and Wooldridge (2002, pp. 534-35; and 2006, p.603). With this procedure we test whether the same variables affecting the probability of a nonzero observation determine also the level of a positive observation (i.e., the number of workers that received training) and, moreover, whether they do so with the same sign, a structure that is assumed by the tobit model (Verbeek, 2004, p.221). We found a lack of any 'dramatic' differences between the estimates of two models - i.e., between probit and adjusted tobit coefficients - implemented separately for East and West Germany, which suggests that tobit estimation is appropriate (Wooldridge, 2006 p.604).

Table 3 contains estimation tobit estimates of the determinants of the number of trained workers for West and East establishments, the associated unconditional marginal effects, and the marginal effects conditional on a positive number of trained workers.

Table 3: Empirical findings, determinants of training intensity (number of trained workers)

Explanatory variables	West Unconditional MFX		West Conditional MFX		East Unconditional MFX		East Conditional MFX	
Number of employees	0.14	***	0.11	***	0.12	***	0.09	***
Proportion apprentices	21.67	***	16.4	***	-3.67		-2.77	
Proportion unskilled	-26.07	***	-19.72	***	-13.71	***	-10.34	***
Proportion part time	-8.67	***	-6.56	***	-1.33		-1.01	
Proportion fixed term contracts	7.21		5.46		6.09	***	4.59	***
Business volume	-0.0022	***	-0.0017	***	0.03	***	0.02	***
Investment in EURO	0.27	***	0.21	***	0.02		0.01	
New technology	4.76	***	3.62	***	2.39	***	1.81	***
Old technology	-0.04		-0.03		-1.65		-1.26	
Work councils	4.59	***	3.46	***	2.17	***	1.62	***
Collective wage agreements	2.07	*	1.57	*	3.38	***	2.53	***
Team working	1.93		1.45		3.34	***	2.47	***
Established before 1990	-0.49		-0.37		-0.93	*	-0.7	*
Good profitability	0.92		0.69		0.34		0.26	
Poor profitability	0.87		0.66		-0.02		-0.02	
ICT investment	7.18	***	5.46	***	3.79	***	2.86	***
Investment foreseen	7.56	***	5.77	***	4.28	***	3.27	***
Agriculture	-1.37		-1.04		-1.57		-1.2	
Mining	-7.22	**	-5.63	**	-4.2	***	-3.29	***
Construction	-1.29		-0.98		-3.06	***	-2.35	***
Trade	7.16	***	5.35	***	2.8	***	2.08	***
Communication	2.35		1.77		-1.56		-1.19	
Finance	26.43	***	19.03	***	0.3		0.23	
Services	7.24	***	5.43	***	1.82	***	1.36	***
Observation summary (total)	**9,385**				**8,085**			
Left-censored observations	3,838				3,525			
Un-censored observations	5,547				4,560			
Right-censored observations	-				-			

Note: Highlighted when differences between East and West Germany found; *, ** and ***, significant at, respectively, the 10, 5 and 1% level of significance.

The results reported in Table 3 suggest that all measures of technological change have statistically significant effects on training, and that these effects except the measure for the investment volume, are sufficiently large to be economically important. We find that establishments operating with new technologies as well as in those with higher investment volume, that have invested in the ICT in the previous year and that foresee investment for the current year, provided more training. These findings confirm our prediction that exposure to technological change requires more skilled workers/enhanced skill intensity, with continuing training being used as a mechanism to provide the required increase in skill intensity.

The expected positive influence of team working is supported for the East German establishments whereas no significant influence is apparent for establishments in the West. Business volume is found to exert a negative influence on the number of trained workers in the West and a positive influence in the Eastern establishments. This is consistent with our discussion on the lack of theoretical explanation for the a priori sign of this variable. The profitability of establishments seems not to influence the extent of training intensity.

West German establishments that train a greater proportion of apprentices were found to provide training to a greater number of workers. However, no such complementarity between initial and continuing training was found for the East. The explanation for this could be that, in comparison to the East, western establishments belong to more technologically dynamic sectors of the economy; hence, besides apprenticeship training, also require a continuous skill enhancement of workers. In support to this, Brussig and Leber (2006) state that the average East German enterprise introduces fewer innovations than its western counterpart does.

We examined whether the influence of apprenticeship training on further training intensity itself depends upon whether the establishment has undergone technological change. To this end, in our empirical specification, we incorporate interaction terms between the proportion of apprentices at the establishments and the following technological change indicators: whether establishments operate with new or old technology; whether establishments invested in ICT in the previous year;

and whether investments are foreseen for the current year (they are not reported for reasons of space but are available on request).

We find that apprenticeship training positively influences the intensity of further training in the West regardless of the presence of technological change; i.e. there is no significant influence exerted by any of the four interaction terms. In contrast, the results for eastern establishments are markedly different. Here, we find that the share of apprentices alone does not influence the number of workers undertaking further training in the first half of the year. However, a negative influence is found when the variable measuring the share of apprentices is interacted with proxies of technological change. In the East, we find that in establishments operating with new technologies, that have invested in ICT and in those that foresee investment for the current year, *the greater the share of apprentices the fewer is the number of workers that have received further training in the last six months*. This may suggest that eastern establishments are able to meet the demand imposed by technological change by providing initial training only and, hence, provide less further training. This again may indicate differences between the technologies that establishments in the two regions adopt. Unfortunately, the data we possess allows no more than speculation on this matter.

With respect to the employment structure, we find that in both western and eastern establishments the greater the share of unskilled workers the fewer the workers receiving training in the first half of the year. The explanation for this is in accordance with Snower's (1996) prediction, which suggests differing degrees of readiness of skilled and unskilled employees to acquire additional knowledge and skills through further training. We also find that a greater share of part-time employees provides disincentives to West German establishments to provide further training but exerts no influence for those in the East. Consistently, the presence of work councils and collective wage agreements entail more training. Finally, we find that establishments with more employees train a greater number of workers. However, this does not indicate that large establishments train more.

To check whether in large firms more workers received training in the first half of the year, we transformed the dependent variable measuring the number of trainees into the share of trained workers. We found no statistically significant influence of the size of establishments on training intensity. In addition, we regressed the number of trained workers with nine additional size dummies, with the '500-999 employees' as the benchmark category, and found that establishments below this benchmark trained less and those with more than 999 employees trained more. In comparison with the manufacturing sector, which is the reference sector, trade, services and finance (in the West only) offer more training, while establishments in mining and construction (in the East only) offer less training. These findings suggest that establishments in the service sectors train more.

Having presented empirical findings, in Table 3.1 we provide findings for technological change measure and that both unconditional and conditional marginal effects. "Conditional" effects estimate changes in the expected (or predicted) intensity of training *for those establishments in which training provision is observed*; whereas "unconditional" effects account in addition for the effect of changing values of the independent variables on *the probability that establishments provide training* (i.e., will change from zero to positive and thus observable). Table 3.1 provides those variables that exhibit a statistically significant influence of technological change on the number and the share of workers that undertook training in the first half of the year). Notice that when differences between West and East are found, those differences turn out to be statistically significant.

Table 3.1 Quantifying the influence of technological change on training intensity

	West		East	
	Dependent variable			
Dependent variable:	**No. workers[a]**	**% trained[b]**	**No. workers[a]**	**% trained[b]**
Median number of employees	**34**		**21**	
All establishments				
Unconditional MFX: additional number/share of workers receiving training due to:				
Volume of investment in million EUROs	0.27			
New technology	4.76	0.04	2.39	0.05

Old technology		-0.02		-0.03
ICT investment	7.18	0.05	3.79	0.05
Investments foreseen	7.56	0.04	4.28	0.06
Only establishments that provided training				
Conditional MFX: additional number/share of workers receiving training due to:				
Volume of investment in million EUROs[c]	0.21			
New technology	3.62	0.03	1.81	0.03
Old technology		-0.02		-0.02
ICT investment	5.46	0.04	2.86	0.04
Investments foreseen	5.77	0.03	3.27	0.05
Number of observations	**9,385**		**8,085**	

a/b) the dependent variable is number/share of workers that have received training during the first half of the year.

In Table 3.1 as a comparator, the median size of establishments is 34 employees in the West and 21 in the East. The magnitude of the tobit marginal effects suggest the following quantitative effects of technological change on training. Conditional on training provision, other factors unchanged, in the West and in the East:

- establishments that operate new technologies on average provided training for an additional four and two workers respectively;
- those establishments that invested in ICT in the previous year were found to train around five and three more workers respectively; and
- those that foresee investments train six and three more workers.

However, an increase in the investment volume by one million EUROs occasions a very small influence on the number of trained workers 0.21 and that only in West Germany.

Next we consider the influence of technological change measures on the proportion of workers that received training in the first half of the year. Our findings indicate that, conditional upon training provision in West and East Germany, in establishments operating with new technologies the share of trained workers is three percent greater than in those operating at the technological norm, while and those that operate with old technologies train two percent fewer. Other factors unchanged, establishments that have invested in ICT in the prior year train the greatest share of workers (an additional of 4% more employees in East and West Germany). Finally, in

establishments that have foreseen investment for the current year the share of trained workers is greater by three percent in western and by five percent in eastern establishments. The unconditional marginal effects, which take into account also the effect of technical progress in changing establishments' decisions about whether to train at all, suggest larger increases in training intensity compared to conditional effects interpreted here.

To summarise, overall our empirical findings provide supportive evidence for our hypothesis that technological change influences both West and East German establishments to train and to train more workers (i.e. a greater share of their workers). In addition, we find some evidence that new management practices induce more training, that German labour market institutions (unions and works councils/codetermination) encourage establishments to train, and that there is a link between the level of skills and training.

Addressing endogeneity and robustness

Our theoretical framework suggests that there may be a two-way relationship between training and technological change: i.e. a potential endogeneity/simultaneity problem, which we attempt to address. Since training is a mechanism for updating workers' skills, this suggests not only that technological change is expected to influence training provision but also that training may influence the probability of workplaces introducing new technologies. Machin and Van Reenen (1998) argue that if firms expect growing workforce skills then it may be less costly for them to adopt new technologies. However the possibility of mutual endogeneity between technological change and training has not been previously acknowledged either in the theoretical literature on training or in empirical investigations. Since we acknowledge that there might be endogeneity, we need to instrument the variable for technological change. Focusing mainly on training intensity, the endogeneity issue will be considered in relation to training intensity only. With panel data, endogeneity can be addressed by taking lagged values of a potentially endogenous variable. Since the variables measuring investment volume and indicating whether establishments invested in ICT refer to the previous year, we consider neither of these to be simultaneously

determined in the training model. Moreover, the current state of technology employed at the establishment refers to an accumulated capital stock and so is unlikely to be influenced by the current flow of training; hence, we consider this variable unlikely to be endogenously determined. However, the final variable measuring technological change is whether investments are foreseen for the current year. This variable presents a potential problem of endogeneity, since it can be argued that training in the first half of the year could determine establishments' current investment plans in the year. To examine this possible link, we estimate a probit model testing for the impact of training intensity on the probability that establishments foresee investments. We find no evidence for this relationship for the West; but do find a positive link for the East German establishments. The latter finding suggests that in the East anticipated investment for the current year is determined by the training provision in the first half of the year. Hence, in this case, there is possible endogeneity between training and this measure of technological change.

Since we suspect and find some evidence that the 'foresee investment' variable may be endogenous in the training model, the next step is to address this problem by finding a suitable instrument for this potentially endogenous variable. It is acknowledged that it is hard to find convincing instruments for adoption of new technology (Machin and Van Reenen, 1998; p.1235). Unfortunately, this appears a problem with the dataset we use since we were unable to find a suitable instrument. As reported above, the likelihood-ratio test for West and East Germany in both cases rejects the null hypothesis that the panel variance is unimportant, suggesting that the panel estimator is different from the pooled estimator and, hence, that we should use the panel estimates. Unfortunately, using panel estimates imposes a problem, since there are no techniques in place to test for endogeneity when dealing with panel data. This together with a lack of a suitable instrumental variable does not permit analysis of the reverse causation from training to technology.

Finally, to check the validity of our estimates, we compare our findings with previous studies related to further training using the IAB dataset. The only relevant studies for comparison with our findings are those by Zwick (2002 and 2006). Using cross section data from 1997, Zwick

found that establishments that operate with new technologies and those that invested in ICT provided more training (a greater share of workers receiving training in the first half of the year). These findings, referring to a year not incorporated in our empirical analysis, support our hypothesis and findings.

Concluding remarks

Empirical investigation in this paper is based on the German IAB establishment panel with employer-reported measures of training. We anticipate that when firms experience technological change establishments are more likely to train (incidence) and also to train more workers/greater proportion of workers (intensity). We apply the probit model for the training incidence using the unbalanced panel for the period 1994 to 2003; and the tobit model for training intensity in a shorter panel consisting of the years 1999, 2001 and 2003. Our findings suggest that establishments operating with new technologies both in the West and East were more likely to provide further training, and that establishments in East Germany with greater investment volume in the previous year were more likely to train. With regard to the training intensity, conditional upon training provision, we find that in West and East Germany alike, in establishments operating with new technologies the share of trained workers is three percent greater than in those operating at the technological norm. Conversely, those establishments that operate with old technologies train two percent fewer workers. Other factors unchanged, establishments both in West and East Germany that have invested in ICT in the prior year train a greater share of workers by four percent. Finally, in establishments that have foreseen investment for the current year the share of trained workers is greater by three percent in the West and by five percent in the East.

Regarding new forms of work practices, we find a consistent positive relationship between the use of team working and the share of trained workers for both West and East. In the West, the training intensity increases with the proportion of apprentices but no significant influence was found for East Germany. Conforming to theoretical predictions, the larger the share of unskilled

and part-time workers (in the West only) the smaller the proportion of workers receiving further training. Also in line with our expectations, establishments with work councils and subject to collective wage agreements train a larger proportion of workers. In comparison with manufacturing, the trade, finance and services sectors offer more training.

In this paper we also investigated the possibility of endogeneity/simultaneity between technological change and training. We acknowledge that a two-way relationship not reflected in the empirical methodology will lead to biased and inconsistent estimates. However, due to a lack of readily available and generally accepted econometric techniques for diagnostic testing with panel data, we could not fully address this issue.

To conclude, our empirical work has provided evidence of a link from technological change to training. In addition, we have taken into account the potential simultaneity between training and technological change. Our findings that technological change induces more training, together with concerns that firms within the EU are not providing sufficient training to maintain competitiveness and reap benefits from technological progress (Booth et al., 2003), may suggest that one way to induce firms to provide more training is by enhancing incentives for firms to undertake more rapid technological change. In addition, our findings indicate that the greater the share of skilled workers the greater the incentives for workplaces to provide more training. This may indicate a complementarity between education and training, hence implying that one way for governments to foster training provision could be also through improvement of the initial human capital of workers, i.e. their education level.

We need to recognise that our empirical analysis is subject to some limitations, stemming from the data used. A limitation of our empirical investigation is related to the dependent variable. The measure for training does not take into account the intensity or length of the training course in which employees participated. Unfortunately, information on training expenditures or average length of training that could break down these differences is not available. In addition, we could only assess the impact of past technology changes on training provision. A more appropriate investigation of our key hypothesis might be to assess also whether firms provide more training

when they expect to introduce modern technologies. These limitations provide opportunities for further research.

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