German Economic Review 6(2): 155–184

Continuing Vocational Training Forms and Establishment Productivity in Germany

Thomas Zwick
Centre for European Economic Research (ZEW)

Abstract. *This paper provides evidence of the productivity effects of different continuing vocational training forms in Germany. Using the waves 1997–2001 of the IAB establishment panel, it is found that formal external courses have the largest positive impact on productivity. Formal internal courses and quality circles have a smaller positive impact. Self-induced learning, participation at seminars and talks and job rotation do not enhance productivity while training on the job has a negative productivity impact. Establishments with an inefficient production structure decide to offer training in order to boost productivity. This paper also shows that taking into account selectivity of the training decision, unobserved time-invariant heterogeneity, human resource practices, as well as establishment and employee characteristics has an important impact on the measurement results.*

JEL classification: *C*23, *D*21, *J*24.

Keywords: Training forms; establishment productivity; panel estimation.

1. INTRODUCTION

Human capital, knowledge and skills are increasingly important competitive assets within establishments. Rapid technological change implies permanent changes in firms' skill demand, skill obsolescence and training needs (Acemoglu and Pischke, 1999). Continuing vocational training, which is usually mainly sponsored by the firms, is therefore perceived as one of the most important measures to gain and keep productivity. Especially the German economy, which is based on a relatively high share of well-qualified employees who frequently work in flexible, complex and diversified quality production, derives its main competitive advantages from human capital and therefore has a large demand for continuing vocational training (Appelbaum and Batt, 1994, pp. 39–43; Roth, 1997). In 1998, German firms accordingly invested on average the substantial amount of 1,128 euros per year per

employee in continuing vocational training (Institut der deutschen Wirtschaft, 2002, p. 99). It is not clear, however, if all firms aim at increasing productivity when they invest in continuing vocational training. Training may also be used as a 'sorting device' that enables employers to determine which employee should be promoted (de Koning, 1994). Several commentators argue that vocational and continuing vocational training in Germany provides employees with knowledge that is only temporarily needed: for example, for infrequent maintenance activities or re-organizations (Roth, 1997). This kind of training is primarily directed at increasing flexibility in emergency situations instead of continuous productivity increases. Therefore, German workers frequently have redundant cognitions, and a part of their skills is not used in daily work (Berg, 1994). Training may also be a necessity when the workforce is not adequately qualified and the firms are forced to retrain workers internally in order to avoid high labour turnover costs and a shortage of skilled workers on the labour market (Zwick and Schröder, 2001). The theoretical literature, therefore, is ambiguous with respect to the productivity effects of continuing vocational training in Germany, and an empirical study is needed.

It will be argued below that, compared to other countries, the German empirical literature on the productivity effects of training is thin. The empirical results from other countries usually cannot be applied to German conditions, however, because the qualifications of the employees, labour relations and training systems are not comparable. As a consequence, more work in this area seems warranted. Another motivation for this paper is that different dimensions of training may generate different productivity effects (Black and Lynch, 1996; Barrett and O'Connell, 2001). It therefore seems important to differentiate between several training forms in order to understand what exactly drives productivity. Some training measures are clearly more popular and expensive than others, and it seems to be crucial to the establishments to know which measures are the right ones for enhancing productivity. To the best of my knowledge, there is not one single representative study on the productivity effects of different training forms for the German economy. This paper therefore concentrates on measuring the productivity effects of several popular continuing vocational training forms in establishment production functions.

Besides closing a gap in the empirical literature, this paper also introduces innovative estimation techniques that take account of estimation problems frequently encountered when productivity effects of training are measured (Kruse, 1993; Dearden *et al.*, 2000; Caroli and van Reenen, 2001). First, firms that offer training may be structurally different from those that do not offer training due to time-invariant unobserved factors, such as management quality, the exposition to technical change, the activity of the personnel department or management–employee relations. This is called 'unobserved heterogeneity bias' and it is considered in this paper by using panel estimation techniques. Second, transitory shocks, such as the introduction

of new technology or a deterioration of market conditions, could change productivity and induce changes in training efforts at the same time. Firms may not decide randomly when they train their employees, and therefore training is not a strictly exogeneous variable in the productivity equation. This source of estimation bias is called 'selectivity bias' and it is examined by adding a correction term containing the probability that an establishment trains. Finally, the productivity pay-off of the training investment may reveal itself only at some point in the future while productivity is decreased during the training period (Bassi *et al.*, 2001). Therefore, this paper measures the productivity effects of the different training forms after one and two years or the effect on average productivity for several years after the training incidence. In addition, this paper indicates the size and direction of the estimation biases incurred by unobserved heterogeneity and selectivity and interprets them intuitively.

Several papers estimate the productivity impact of training by means of very parsimonious specifications. This paper demonstrates that the inclusion of a broad variety of additional establishment characteristics and especially of further human resource practices improves the estimation and reduces the measured productivity impact of training. Estimations excluding these variables therefore may suffer from omitted variable bias, and the training measures may pick up productivity effects of other variables that are closely correlated with training (Black and Lynch, 1996; Ichniowski *et al.*, 1997; Wolf and Zwick, 2003).

This paper is constructed as follows. First, a short survey presents the main results of the literature on the productivity effects of training at the establishment level. Then, an empirical model correcting for unobserved time-invariant heterogeneity and selection bias is developed on the basis of a standard Cobb–Douglas production function. The next section presents the data basis. The fifth section first explains the training decision of the establishments and then presents several regressions that measure the impact of different training forms on productivity. These regressions show that omitted variable bias, selection bias and unobserved heterogeneity bias matter. The last section concludes.

2. LITERATURE

In this section, a short survey of the results in the empirical literature on the productivity effects of training is given. It places considerable emphasis on the data and the estimation techniques used (see also the literature reviews in Bartel, 2000; Dearden *et al.*, 2000). Comparing the results obtained in this study with those in the literature, it becomes clear that the estimation technique and the data basis are of crucial importance for measuring the productivity impacts of continuing vocational training. Only studies using establishment- or firm-level data from several sectors are included, and

special attention is given to studies that explore the productivity effects of different training forms.

All studies surveyed find a positive (although frequently insignificant) impact of training on productivity. There are clear differences in the productivity impact of different training forms, however. General training has a higher impact on productivity than specific training (Barrett and O'Connell, 2001). Barrett and O'Connell (2001) argue that, in comparison with specific training, general training is more valuable to employees because it increases employability elsewhere. Therefore, their motivation to absorb and apply the training contents is higher. Another argument is that employees may perceive general training as a gift or a sign of loyalty from their employers and because of that react by increased effort (and hence productivity). Off-the-job training has a higher impact on productivity than on-the-job training (Black and Lynch, 1996; Dearden *et al.*, 2000). Black and Lynch (1996) stress that there might be two reasons for this observation: off-the-job training may lower the output loss associated with on-the-job training, while those employers who train their workers off-the-job may invest in more advanced and time-intensive skills development. Finally, it is demonstrated that the training content also matters: computer skills development (in contrast to teamwork or supervisor training) has a positive impact on the productivity of non-manufacturing industries (Black and Lynch, 1996).

The remainder of the literature survey makes clear that the choice of estimation techniques may have a decisive impact on the results. Bartel (1994) is the first to estimate a simple cross-section production function including formal training programmes. The data basis is a selective sample of almost 150 firms from the Columbia survey in the USA. Bartel does not find an effect of formal training on productivity in the same year. Possibly, her estimation is biased by unobserved heterogeneity between firms which leads to a correlation between the formal training measure and the error term (Griliches and Mairesse, 1998). In order to avoid this bias, she then estimates a first-difference model in which the change in labour productivity between 1983 and 1986 is regressed on changes in the incidence of training programmes. She finds that businesses which operated below their expected labour productivity levels in 1983, implemented new employee training programmes after 1983 that brought productivity up to the level of comparable businesses by 1986. Therefore, the productivity effects of the considered formal training measures are negatively biased by unobserved heterogeneity. Barrett and O'Connell (2001) apply the same estimation strategy to Irish firms surveyed in 1993 and 1995. The response rate in the second wave was only one-third of those firms participating in the first wave. They differentiate between the impact of general and of specific training days per employee and find that, unlike the level of specific training, the level of general training has a significantly positive effect on productivity growth.

Black and Lynch (1996) estimate a standard Cobb–Douglas production function including training intensity, three specific types of training activities and several controls for other workplace practices. The estimations are based on a dataset from the 1994 American National Centre on the Educational Quality of the Workforce (EQW). They find no impact of the share of employees trained in 1990 and 1993 on sales in 1993. Nevertheless, a high percentage of formal training outside working hours has a positive impact on productivity within the manufacturing sector. Their cross-section study is prone to endogeneity bias, however. Therefore, Black and Lynch (2001) add panel data from the Longitudinal Research Database (LRD) to their data on training and other workplace practices used in their 1996 article. This halves their sample size. They check for observed and unobserved time-invariant heterogeneity between the firms by estimating a Cobb–Douglas production function in several fixed-effects panel models. As training and other workplace practices are almost time-invariant in a short panel, they only include capital and labour in the first estimation step. On the basis of these regressions, they calculate the average firm-specific, time-invariant residual. In a second step, they regress this average establishment residual on training and other workplace practices. In the more recent paper, training measured by the number of employees trained still has no impact on productivity in any regression while some other personnel measures do have one. Black and Lynch (2001, p. 443) admit that their estimation technique only corrects for endogeneity in the parameters included in the first step (for example, capital and labour), and therefore it is prone to selectivity bias in the coefficients included in the second estimation step (for example, training).

Ballot *et al*. (2001) study the impact of the level of human capital and R&D expenditures on firm performance for French and Swedish data. They present results for several panel estimation techniques. Their main result is that the impact of training hours and expenditures for training per employee on firm productivity strongly depends on the estimation technique used. In their preferred specification, a system GMM estimation that takes account of the possible endogeneity of labour, capital, training and R&D in the productivity estimation, training has a positive and significant impact on the value-added in France, whereas in Sweden the effect is insignificant. Their instruments (lagged values of the explanatory variables by one or two years) may be weak, however, because all instrumented variables and the dependent variable may be affected by shocks that take longer than one or two years (Dearden *et al*., 2000). Their panel includes data for a period of six years and therefore it is too short to introduce longer lags. In addition, their specification is very parsimonious. Only tangible assets and their interactions are taken into account, while further firm and personnel characteristics remain absent. Finally, their sample size, consisting of 90 firms in France and 270 firms in Sweden, is small and specific. The French dataset only contains large firms that all engage in training, while the Swedish dataset also includes non-training firms.

Bellmann and Büchel (2001) estimate the productivity effects of training and examine the selectivity bias in the decision to offer training or not. On the basis of the German IAB establishment panel, they use an estimation of a cross-section Cobb–Douglas production function including training intensity. They first model the training decision of an enterprise in a probit estimation and then add the probability to provide training to the production function estimation (see also Greene, 2000, and Section 5 in this paper). They find that training intensity has a positive and significant effect on productivity. After correcting for selectivity, training intensity has a slightly higher but now insignificant effect on productivity. Their cross-section results may suffer from unobserved heterogeneity, however. Another problem regarding their study is that they do not take into account further probably complementary workplace practices or establishment characteristics.

Dearden *et al*. (2000) present a study on the productivity impact of training on the industry level in Great Britain. They use a long panel dataset between 1983 and 1996 that entails information on training in every year for 94 industries. They address unobserved heterogeneity as well as selectivity of training simultaneously by using a system GMM estimation that includes levels, first differences and lags of capital, labour, as well as training intensity. In addition, they calculate the impact and the sign of the biases incurred when training is taken exogenously in the estimation. They find a positive and significant effect of training on sector productivity. In addition, they find that the productivity effect mainly stems from off-the-job training instead of on-the-job training. The estimation coefficient significantly increases when endogeneity of training is taken into account. There are two major drawbacks of their approach, however. First, they combine data on different aggregation levels which may lead to aggregation bias. Second, the lagged variables that are used as internal instruments for current levels of training, capital and labour in their regressions might be weak. In addition, they do not control for additional personnel management measures, and therefore their regressions might incur omitted variable bias. Finally, their information on training covers only four weeks per year, respectively, and service firms have been dropped due to 'measurement problems' in most regressions.

A comparison of the results produced by different estimation techniques shows that correcting for unobserved time-invariant heterogeneity or endogeneity usually increases the estimated productivity impact of training, while the accuracy of the estimations decreases (Dearden *et al*., 2000).

3. DERIVATION OF THE EMPIRICAL MODELS

The available empirical literature on the productivity effects of training distinguishes only very crudely between different training forms. Especially the difference between general and specific training (Barrett and O'Connell, 2001), different training topics (Black and Lynch, 1996) and training for

Table 1 Training costs per employee and incidence of different training forms

Training form	Expenditures[a]	Incidence[b]
Formal internal training	562	37%
Formal external training	215	55%
Seminars and talks	39	42%
Training on the job	111	40%
Job rotation	Not available	9%
Quality circles	Not available	13%
Self-induced learning	35	14%

Source: [a] Institut der deutschen Wirtschaft (2002); figures in euros for 1998.
[b] IAB Establishment Panel; wave 1997; own calculations.

managers versus other employees (Ballot *et al.*, 2001) has been analysed. The effects of other training forms that may be chosen by the personnel department or the employee to reach certain qualification goals such as internal versus external formal courses, job rotation versus training on the job, self-induced training versus passive participation at seminars etc., have not been analysed thoroughly, however. This paper therefore focuses on the productivity impact of seven popular training forms: formal external and internal training, self-induced learning, quality circles, training on the job, seminars and talks, or job rotation (see the incidence of the different training forms in 1997 for German establishments in Table 1).

3.1. Cross-section estimation

In order to estimate the impact of the incidence of different training forms on establishment productivity, a standard Cobb–Douglas production function is used. Value-added Y_i of establishment i is a function of capital K_i, labour L_i, and a Hicks-neutral efficiency parameter A_i. It is assumed that every training form shifts productivity by a certain amount (Black and Lynch, 1996). Therefore, seven dummy variables $D_{i,j}$ are added to the production function, indicating whether an establishment offered one or more of the seven training forms:

$$Y_i = A_i * K_i^{\beta} * L_i^{\gamma} * D_{i,j}{}^{\tau_j} \quad \text{with } j = 1, \ldots, 7$$

Many further factors in addition to capital, labour and continuing vocational training are empirically relevant for establishment productivity. In order to avoid omitted variable bias, a large vector V_i of further explanatory variables is considered in the empirical model (Dearden *et al.*, 2000; Black and Lynch, 2001). In particular, other dimensions of workforce heterogeneity – such as

the share of qualified employees – and of establishment heterogeneity – such as the state of technical equipment or the legal form – and a dummy for establishments investing in information and communication technology (IT), co-determined or exporting establishments are included. Training measures are closely correlated with other human resource measures that increase the participation of employees and are frequently labelled 'high performance workplaces' (Whitfield, 2000; Barrett and O'Connell, 2001; Wolf and Zwick, 2003). In order to avoid that the training dummies pick up productivity effects from other personnel measures, a few crucial additional controls for relevant personnel measures are added: shift of responsibilities to non-managers, teamwork, groups with their own cost responsibility, strong selection procedures when hiring new employees, employee share ownership and profit sharing.

As training cannot be expected to have an instantaneous effect on productivity and employees may actually be less productive during the training period (Bartel, 1995; Dearden *et al.*, 2000; Bassi *et al.*, 2001), different lags between $D_{t-z,i,j}$ and $Y_{t,i}$ are used with t being an indicator for the year and z an indicator for the lags used in the cross-section specification; see equation (1). This also allows us to analyse the time path in the productivity impact of different training forms. The cross-section estimation model is based on the following log-linear equation:

$$\ln Y_{t,i} = \ln A_{t,i} + \beta \ln K_{t,i} + \gamma \ln L_{t,i} + \tau_j' D_{t-z,i,j} + \delta' V_{t,i} + \varepsilon_{t,i} \quad \text{with } j = 1, \ldots, 7 \quad (1)$$

3.2. Endogenous switching regression approach

The empirical results of the estimated productivity function (1) may be biased, because establishments do not decide to offer a certain training measure randomly. Investment in training is an endogenous decision of the establishment instead, which depends for example on the productivity effects and the investment costs of the training measure and other factors (Dearden *et al.*, 2000; Bellmann and Büchel, 2001; Caroli and van Reenen, 2001). Establishments may, on the one hand, offer training when they are in a slack period, because training does not cause high productivity costs then. On the other hand, establishments may invest in training when they have enough money for these costly measures, i.e. in boom periods with high productivity (Zwick, 2004a). Therefore, the impact of different training measures on productivity can be interpreted as a treatment effect with endogenous choice of the treatment (Maddala, 1983; Greene, 2000). The first measure against endogeneity is to take only lagged training measures as explanatory variable for value-added. This should capture most of the endogeneity problem (Bassi *et al.*, 2001; Caroli and van Reenen, 2001). It can be shown, however, that the decision to offer training or not still is not truly exogenous. This seems plausible, because positive or negative shocks that might simultaneously

affect the training decision and the productivity usually take longer than one year, and also the productivity effects of training can be expected to occur after more than one year.

Selectivity can be corrected by estimating first the decision to adopt a training measure using external identifying variables and correcting in a second step the production function by adding a correction term indicating the probability that a certain establishment introduced this training measure.[1] The production function of those establishments that offer training and of those that do not is known. Therefore, a so-called endogenous switching regression model which includes both types of establishments seems appropriate here (Maddala, 1983; Wolf and Zwick, 2002). It would have been desirable to correct selectivity individually for all different training forms. This does not seem to be achievable, however, because the different training categories are not mutually exclusive and therefore a multivariate probit analysis in the first estimation step explaining the decision to introduce a certain training measure is not possible. In order to estimate the probability to offer each training form separately, the assumption is necessary that the decision to introduce a certain training form is independent from the other training alternatives. This assumption would incur an estimation bias, because some training forms are strongly correlated with each other (this applies especially for the correlations between training on the job and seminars and talks on the one side and formal courses on the other; see Table A.5). The strong correlation between the individual training measures also prevents an empirical distinction between those explanatory variables that are valid for one training measure but not for the other. Finally, not enough external identifying variables are available for all seven measures individually. Therefore, a single correction term characterizing the decision of the establishment to offer training (i.e. at least one of the seven training measures) or not seems the best that can be achieved here.

The decision to offer training or not in period t can be specified as a reduced form in a probit model where the dependent variable $I_{t,i}$ has the value one when the establishment offers at least one of the training measures and zero otherwise. The latent variable $I^*_{t,i}$ is therefore the difference between benefits and costs of offering continuing vocational training and can be defined as:

$$I^*_{t,i} = \delta' Z_{t,i} + u_{t,i} \tag{2}$$

where $Z_{t,i}$ is the vector of relevant variables for the decision of the establishment to engage in training or not in period t. An establishment introduces training ($I_{t,i} = 1$) if $I^*_{t,i} > 0$ (or $\delta' Z_{t,i} > -u_{t,i}$) and it does not invest in training ($I_{t,i} = 0$) if $I^*_{t,i} \leq 0$.

1. This correction term is also called 'normal hazard function' (Heckman, 1976).

According to Maddala (1983) or Greene (2000, p. 933), the production function (1) can be consistently estimated in an endogenous switching regression model, i.e. by adding a selection correction term for training establishments and non-training establishments as follows:

$$
\begin{aligned}
E[\ln Y_{t,i} | I_{t-z,i} = 0] &= \beta' X_{t,i} + \sigma \frac{-\varphi(\gamma' Z_{t-z,i})}{1 - \Phi(\gamma' Z_{t-z,i})} \\
E[\ln Y_{t,i} | I_{t-z,i} = 1] &= \beta' X_{t,i} + \tau_j' D_{t-z,i,j} + \sigma \frac{\varphi(\gamma' Z_{t-z,i})}{\Phi(\gamma' Z_{t-z,i})} \quad \text{with } j = 1, \ldots, 7
\end{aligned}
\tag{3}
$$

where $X_{t,i}$ is the complete vector of explanatory variables from equation (1) without the training variables, i.e. $V_{t,i}$ plus capital, labour and the constant, while $\varphi(\gamma' Z)$ is the density function and $\Phi(\gamma' Z)$ the distribution function of the estimated parameters in equation (2). The parameter σ therefore measures the covariance between the error terms in the production function (1) and the selection equation (2), $\sigma = \text{cov}(u_{t,i}, \varepsilon_{t,i})$.

3.3. Panel estimation

Even if selectivity in the implementation of continuous training is controlled, the cross-section production function estimation may be biased, because other explanatory variables (especially capital and labour) are endogenous in the production function estimation (Griliches and Mairesse, 1998; Blundell and Bond, 1999). Important reasons for the endogeneity of labour, capital and other variables in the production function may be that unobserved time-invariant factors, such as management quality, industrial relations or the impact of technological change, have an impact on the explanatory variables *and* on the value-added. A possibility to correct for biases due to omitted but time-invariant establishment-specific variables is to use panel estimation methods that eliminate the establishment fixed effects. When, for example, in a simple fixed-effects estimation the deviations from an establishment's mean or first differences of equation (1) are taken, all time-invariant fixed effects drop out. This also means, however, that the impact of observed time-invariant effects cannot be taken into account. Within two or three years, the training decision and most other employee and establishment characteristics in V_i do not change much, and therefore the ratio between signal and noise is low if the incidence of different training forms and other quasi-fixed variables are included into a simple fixed-effects estimator (Dearden *et al.*, 2000). There are only four observation periods, and information on several explanatory variables is not available in every year. Therefore, not all variables can be included in a fixed-effects estimation that is based on the changes in the variables over time, and the two-step procedure proposed by Black and Lynch (2001) is adopted here. In the first step, the productivity impact of the variable production factors (capital and labour) as well as of time and of

industry dummies (in order to control for differences between sectors and within the business cycle) is estimated. For this purpose, panel estimation techniques are used that take account of unobserved time-invariant heterogeneity. Then the establishment-specific, time-invariant component of the residual can be calculated. In the second step, the average establishment fixed effect is regressed on the quasi-fixed explanatory variables in V and the training dummies D.

The first step of the panel regression, therefore, can be written as follows:

$$\ln Y_{i,t} = \ln A_{i,t} + \beta \ln K_{i,t} + \gamma \ln L_{i,t} + \delta' P_t + \sigma' S + v_i + \varepsilon_{i,t} \tag{4}$$

with v_i the unobserved time-invariant fixed effect, $\varepsilon_{i,t}$ the idiosyncratic component of the error term, S the industry dummies, and P_t the time dummies. The fixed effect v_i is the establishment-specific difference from productivity expected on the basis of the inputs and controls. This time-invariant variable therefore measures whether establishment productivity structurally is below or above that of the other establishments during the observation period. It serves as a dependent variable for the second estimation step. Here, the quasi-fixed variables, such as the different training forms, establishment characteristics or personnel measures, explain these fixed effects:

$$v_i = \beta' V_{t,i} + \tau' D_{t,i,j} + \zeta_{t,i} \quad \text{with } j = 1, \ldots, 7 \tag{5}$$

The fixed-effects estimation addresses endogeneity biases that may arise when estimating the coefficients of capital, labour, industry and time period on value-added. It does not address biases arising in the second step when the vector of coefficients associated with training forms and the other almost time-invariant variables included in (5) are estimated on the fixed effects. These biases may originate from correlations between the second-stage regressors and unobserved establishment characteristics or with the average of the idiosyncratic shocks (Black and Lynch, 2001). In analogy to the argument for the cross-section regression above, an establishment's decision to adopt a particular training measure may be related to business performance or to the position of the establishment in the business cycle. Therefore, also the selectivity correction term (the normal hazard function) of equation (3) for the decision of the establishment to offer training should be added to equation (5). This corrects for unobserved heterogeneity in the production function and the selectivity bias in the training decision simultaneously:

$$\begin{aligned} E[v_i|I_{t,i} = 0] &= \beta' V_{t,i} + \sigma \frac{-\varphi(\gamma' Z_{t,i})}{1 - \Phi(\gamma' Z_{t,i})} \\ E[v_i|I_{t,i} = 1] &= \beta' V_{t,i} + \tau_j' D_{t,i,j} + \sigma \frac{\varphi(\gamma' Z_{t,i})}{\Phi(\gamma' Z_{t,i})} \quad \text{with } j = 1, \ldots, 7 \end{aligned} \tag{6}$$

For the first-step estimation, the SYS-GMM estimator, proposed by Arellano and Bover (1995), is used instead of a simple fixed-effects estimation.[2] There are several reasons for this decision (Black and Lynch, 2001; Hempell, 2005). The SYS-GMM avoids the poor finite sample properties of the simple fixed-effects estimator or the simple GMM estimator that takes first differences to eliminate unobserved firm-specific effects and uses lagged internal instruments to correct for simultaneity in the first-differenced equations. Both estimators produce implausibly low capital coefficients and returns to scale, because measurement errors in the explanatory variables (especially capital) bias the coefficients towards zero. In addition, the lagged levels of capital or labour are usually only weakly correlated with the subsequent first differences of these variables and therefore have a weak explanatory power (Griliches and Mairesse, 1998; Blundell and Bond, 1999). In order to avoid this problem, the SYS-GMM estimator uses the lagged first differences as instruments for the current input values in levels in addition to the usual lagged levels as instruments for equations in first differences. The SYS-GMM estimator avoids inconsistencies incurred by unobserved time-invariant heterogeneity and simultaneity of the choice of capital, labour and output, usually produces reasonable input coefficients in estimations of production functions and therefore is preferable to a fixed-effects or a simple GMM estimation (Blundell and Bond, 1999; Dearden *et al.*, 2000; Ballot *et al.*, 2001).

4. THE DATA

The empirical analysis of the impact of seven different training forms on establishment productivity is performed on the basis of the IAB establishment panel (for detailed information see Kölling, 2000; Bellmann and Büchel, 2001). The establishments in this panel are drawn from all establishments in Germany which employ at least one person who has a social security number. Therefore, only establishments consisting of employees not covered by social insurance (mainly farmers, mine workers, artists and journalists) along with public enterprises with only civil servants are excluded. There is a large set of questions that is asked every year on production, investment, industry sector, employee structure, personnel problems, business strategy and vocational training. Since 1993, the survey has been held in the middle of every year. Some questions, such as those on average employment during one year, output and profit situation, are therefore asked retrospectively in the following wave. Every year, additional questions are added on an irregular basis. In the waves 1997 and 1999, detailed information on the training behaviour of the establishments was collected. After the filter question 'Did

2. These regressions were computed using the two-step estimation procedure in the DPD98 program developed by Arellano and Bond (1998) running in GAUSS.

your establishment support continuous vocational training in the first part of 1997?', it was asked: 'For which of the following internal or external measures, were employees exempted from work or were costs completely or partly taken over by the establishment?'. There were eight options to choose from: formal internal training (courses, seminars), formal external training, seminars and talks, training on the job (introductory training, instructions), participation at seminars and talks, job rotation, self-induced learning (computer-assisted learning programmes, text books), quality circles and additional continuous vocational training measures the respondents had to specify themselves. In this paper, the impact of the first seven different training forms in the first six months of 1997 on productivity in 1998 and 1999 is calculated. In addition, panel information from the waves 1997 until 2001 is used.

Productivity is approximated by value-added, i.e. turnover minus payments to third parties and inputs. Capital stock is not directly measured in the dataset and therefore it is approximated by total investments minus expansion investments. The logic behind this is that establishments on average write-off a fixed share of their capital and replace this yearly. Implicitly it is therefore assumed that replacement investments equal capital depreciation. Investments are deflated by the input price index of the German Federal Statistical Office (Statistisches Bundesamt, 2001). Value-added is depreciated by the product price index for different sectors (Statistisches Bundesamt, 2001). Only profit-oriented establishments and those that have not been merged with other establishments or themselves have merged with other establishments are included. In 1997, we have 5,675 establishments in the gross sample, in 1998 there are 6,192, in 1999 there are 6,886, and in 2000 there are 10,578 establishments. Descriptive statistics of the data used can be found in Tables A.1 to A.4 in the Appendix.

5. RESULTS

5.1. The training decision of the establishment

About one-third of the establishments in Germany do not invest in continuing vocational training at all. In 1997, about 64% of the commercial establishments offered training for their employees, while on average 19% of the workforce in these establishments participated in continuing vocational training. In 1999, the number of training establishments (calculated also from the IAB establishment panel) increased to 66% while training intensity was 21%. The expenditures for different training forms are differing widely; see Table 1. While the enterprises spend by far the most money per employee on internal and external formal courses, expenditures for self-induced learning and participation at seminars and talks are considerably smaller. Also the incidence of different training forms varies. Besides formal training, many establishments offer training on the job and participation at seminars,

trade fairs or talks. Job rotation, quality circles and self-induced training are much less widespread.

This paper concentrates on the influence of the different training forms in 1997 on productivity in the years 1998 and 1999. In the cross-section regressions according to equation (1), therefore $t = 1998, 1999$ and $z = 1, 2$. It will be shown that although lagged training variables are used, nevertheless the endogeneity of the establishment's decision to train is of importance for the estimation results. In this section, the selection equation (2) to offer training in 1997 is estimated. In order to effectively control for selectivity in the productivity estimation, external identifying variables have to be found that have a significant influence on the decision to train but not on productivity (Greene, 2000). This paper uses a unique set of questions that identifies expected skill gaps and the reaction of the personnel department on skill shortages as suitable identifying variables for this decision. When establishments expect skill gaps in the future, because some employees will be on maternity leave or made redundant in the next two years or because the demand for skills increases in general, this may induce them to introduce training now (Zwick, 2004a). It can be shown that productivity in 1998 and 1999 is not affected by these expectations in 1997, which means that there is no strong correlation between the expected skill gaps over time or between the expected and the actual skill gaps. Moreover, the preferred reaction of the establishment (i.e. mainly the reaction of the personnel department) on skill shortages has the same statistical properties. When the establishment mainly reacts by additional apprenticeship training or continuing vocational training of the employees on skill gaps (instead of a high priority on hiring skilled employees from the labour market), this increases the probability that the establishment offers training, but it does not have an impact on productivity.

In addition, the usual explanatory variables for the inclination of the establishment to train found in the literature, such as the size of the establishment (measured with four dummies because it cannot be expected that the impact is log-linear in employment), the share of qualified employees, a dummy for investors in IT, state-of-the-art technical installations, a dummy for establishments with collective wage agreements, co-determination and apprenticeship training, sector dummies and the location of the establishment in East or West Germany are added (Düll and Bellmann, 1998; Lynch and Black, 1998; Bellmann and Büchel, 2001; Gerlach and Jirjahn, 2001; Zwick, 2004a). The determinants of the training decision according to equation (2) are summarized in Table 2.

The regression shows that most German establishments react on skill shortages by additional training efforts because the external skilled labour market is thin (Roth, 1997; Zwick and Schröder, 2001). Therefore, it is not surprising that establishments expecting that workers will leave, be on maternity leave or establishments expecting that they will encounter difficulties in finding new skilled workers step up training (Zwick, 2004a).

Table 2 Probit estimation to explain if an establishment trains or not, 1997

Exogenous variables	Coefficients	*z*-Value
Redundancies expected	0.303***	4.72
Many employees are expected to be on maternity leave	0.332***	3.21
High qualification need expected	0.565***	6.94
Apprenticeship training reaction on skill shortages	0.222***	4.32
Training reaction on skill shortages	0.652***	13.08
Establishment size 20–199	0.616***	12.67
Establishment size 200–499	1.119***	10.47
Establishment size 500–999	1.239***	7.32
Establishment size 1,000 +	1.661***	5.38
Co-determination	0.258***	3.81
Share of qualified employees	0.633***	9.03
State-of-the-art technical equipment	0.199***	4.65
Investor in IT	0.244***	5.29
Collective wage agreement	0.213***	4.82
Apprenticeship training	0.457***	10.01
15 sector dummies and East Germany dummy	Yes	
Pseudo-R^2	0.32	
Number of observations	5,629	

Notes: All variables pertain to year 1997 except co-determination which is only available for 1998.
*** Significant at the 1% level; the standard errors are heteroscedasticity-corrected.
Source: IAB Establishment Panel; waves 1997 and 1998; own calculations.

It can also be anticipated that establishments that give a higher priority to additional apprenticeship training and continuing vocational training efforts instead of hiring skilled employees from the labour market when they have vacancies for skilled jobs are more prone to offer training. It is well known that IT investments and state-of-the-art technical equipment induce continuing vocational training needs (Düll and Bellmann, 1998; Dearden *et al.*, 2000; Gerlach and Jirjahn, 2001). Large establishments usually are more inclined to train, because they frequently have an own training department and the fixed costs of training can be spread over a larger number of employees (Lynch and Black, 1998). Collective wage agreements frequently also entail fringe benefits such as training, and a co-determined management gives continuing vocational training a higher priority. The higher the qualification level of the employees, the higher is the return from training, and therefore establishments with a larger share of qualified employees tend to train more (Zwick, 2004a). Finally, establishments which offer apprenticeship training in order to provide the needed skills frequently also provide continuing vocational training opportunities for their employees. All the empirical correlations shown here have also been empirically shown for German establishments, for example by Düll and Bellmann (1998), Bellmann and Büchel (2001), Gerlach and Jirjahn (2001) and Zwick (2004a). The East

Germany dummy and the sector dummies are jointly significant. In comparison to the banking sector – which is the reference sector – agriculture, the consumption goods industry, retail and wholesale trade, and interestingly also educational establishments offer significantly less training, while insurance and business services offer more training (not reported in Table 2).

5.2. Estimation of the productivity effects of different training forms

In order to estimate the productivity effects of seven popular continuing vocational training forms and demonstrate the impact of unobserved heterogeneity bias, selectivity bias and omitted variable bias on the estimation results, first equation (1) without selection correction is estimated. The estimation results for the lagged impact of the different training forms offered during the first half of 1997 on value-added in 1998 and 1999 are shown in Table 3. In addition to capital and labour, it is taken into account that the literature shows that qualified employees, investments in IT and state-of-the-art technical equipment usually increase establishment productivity (Black and Lynch, 2001). Establishments facing international competition and establishments with co-determination are frequently also more productive (Wolf and Zwick, 2003; Zwick, 2004b). The literature also indicates that dummies for employee participation, teamwork, units with own costs and results accounting, stringent hiring rules and incentive payments should be added as indicators for several dimensions of personnel management strategies that may be relevant for productivity (Black and Lynch, 2001; Wolf and Zwick, 2003). Those personnel management measures are observed in 1998 only. Therefore it has to be assumed that there is not much variation between two years when this information is also included in the cross-section estimation for 1999. Finally, 15 sector dummies, four legal forms and a dummy for East German establishments are added in order to capture the differences in productivity between the sectors and the productivity gap of East German establishments.

The estimation results of equation (1) in Table 3 reveal that formal external courses in 1997 have a positive significant impact on productivity in 1998 and 1999. While the productivity impact of external training increases from 1998 to 1999, the impact of formal internal courses has a positive impact on productivity in 1998 only and there is no effect in 1999. Training on the job has a persistent negative effect on productivity. Training circles only create a positive productivity impact with a lag of more than one year. All other training forms do not have an impact on productivity. In addition, it is found that the establishments produce with capital intensity between 0.16 and 0.18 depending on the estimation specification.[3] The additional explanatory

3. The capital intensity estimated is lower than frequently measured, but it is comparable to those found in other cross-section estimations that use investments as proxies for capital (Ballot *et al.*, 2001; Black and Lynch, 2001). The measurement errors for capital are more

Table 3 Lagged productivity effects of different continuing vocational training forms, OLS regressions

	Equation (1), for 1998		Equation (3), for 1998		Equation (1), for 1999		Equation (3), for 1999	
Exogenous variables	Coefficients	*z*-Values	Coefficients	*z*-Values	Coefficients	*z*-Values	Coefficients	*z*-Values
Capital	0.159***	8.99	0.158***	8.91	0.156***	12.70	0.176***	10.16
Labour	0.778***	25.96	0.773***	25.68	0.785***	36.93	0.734***	24.19
Formal external courses 1997	0.114**	2.16	0.197**	2.50	0.175***	3.37	0.341***	3.98
Formal internal courses 1997	0.171***	2.92	0.190***	3.23	−0.049	−0.78	−0.023	−0.35
Training on the job 1997	−0.127*	−2.09	−0.107*	−1.75	−0.114*	−1.74	−0.092	−1.41
Seminars and talks 1997	−0.056	−1.03	−0.035	−0.61	0.162	0.27	0.055	0.88
Job rotation 1997	−0.036	−0.42	−0.036	−0.43	−0.098	−1.06	−0.105	−1.11
Self-induced learning 1997	0.098	1.55	0.101	1.59	0.048	0.68	0.038	0.56
Quality circles 1997	0.089	1.28	0.086	1.24	0.276***	3.96	0.273***	3.77
Share of qualified employees	0.339***	3.73	0.348***	3.82	0.440***	5.87	0.395***	3.78
Exporter	0.222***	3.55	0.218***	3.48	0.187***	4.02	0.171**	2.62
State-of-the-art technical equipment	0.114***	2.49	0.116**	2.53	0.112***	3.16	0.210***	4.34
Investment in IT	0.058	1.30	0.052	1.16	0.119***	2.79	0.119**	2.08
Co-determination	0.175***	2.77	0.175***	2.76	0.205***	4.21	0.258***	3.83
Individual establishment	−0.346***	−5.83	−0.350***	−5.92	−0.327***	−6.62	−0.364***	−5.13
Partnership	−0.003	−0.04	0.001	0.02	−0.049	−0.90	−0.050	−0.61
Publicly listed company	0.052	0.51	0.054	0.53	−0.050	−0.61	−0.066	−0.64
Employee participation	0.084	1.57	0.083	1.57	0.074	1.53	0.066	1.09
Teamwork	−0.033	−0.55	−0.032	−0.54	−0.037	−0.73	−0.015	−0.25
Units with own costs and results accounting	−0.058	−0.93	0.053	0.86	−0.057	−0.94	−0.010	−0.14
Stringent hiring rules	0.014	0.26	0.010	0.19	−0.005	−0.09	0.058	0.95
Incentive payments	0.085	1.36	0.083	1.34	0.161***	3.14	0.109*	1.75
Selection correction term			0.075	1.39			0.164***	2.73
Constant	9.728***	47.74	9.768***	53.54	9.781***	73.47	9.541***	49.53
15 sector dummies and East Germany dummy	Yes		Yes		Yes		Yes	
Number of observations	1,451		1,451		1,219		1,218	
Adjusted R^2	0.89		0.89		0.87		0.88	

Notes: All variables pertain to the year of the dependent variable besides the training variables that pertain to 1997 and the human resource measures that pertain to 1998. ***Significant at 1% level; **at 5% level; *at 10% level; the standard errors are heteroscedasticity-corrected.
Source: IAB Establishment Panel; waves 1997–2000; own calculations.

variables have the expected signs: the share of qualified employees and the dummies for exporting establishments, establishments that invest in IT, have state-of-the-art equipment and are co-determined all have a positive (but partly insignificant) impact on productivity. Individual establishments, i.e. establishments with full liability of one person, are significantly less productive than companies with limited liability (the reference category). Most personnel management measures are individually insignificant, but jointly they have a significantly positive impact on productivity (Black and Lynch, 2001; Wolf and Zwick, 2003). The East Germany dummy and the sector dummies are also jointly significant.

In contrast to Bartel (1994), for example, the size of the estimated productivity impact of training is reduced when further variables are added to matrix V_i, while the explanatory power of the regression increases. In a production function regression entailing besides capital, labour and training intensity only the East Germany dummy and the 15 sector dummies, the parameters of almost all training forms are higher than in the estimation with all control variables.[4] A parsimonious estimation that only takes labour, capital, the training forms and very few additional control variables into account therefore tends to overestimate the productivity impact of most continuing vocational training forms in Germany.

In order to correct for selectivity bias in the cross-section regression, the selection correction terms on the basis of the probit estimates in Table 1 are added to the estimation of equation (3) in Table 3. Both selection correction terms are positive, but only the term for 1999 is significant. The estimates for the different training forms are (with a few exceptions) higher in the specification that takes account of the decision of the establishment to offer training. Especially strongly affected are the coefficients of formal external training and training on the job. We learn from this exercise that establishments might have a higher inclination to train in times of a productivity disadvantage. Establishments probably train in slack periods, i.e. when it is cheap to engage employees with other tasks than production, or they train in order to catch up with the productivity level of their competitors. This pattern is also found in several other studies (Bartel, 1994; Dearden *et al*., 2000; Black and Lynch, 2001). Nickell *et al*. (2001) show that British

severe than for labour and decrease the estimated productivity impact of capital (Griliches and Hausman, 1986). A construction of the capital stock by the perpetual inventory method (Hall and Mairesse, 1995) that depends on the assumption of a constant investment growth rate and a constant linear depreciation rate for capital leads to similar estimation results, because the estimation period is rather short.

4. The exact coefficients for 1998 are: formal external courses: 0.12; formal internal courses: 0.20; training on the job: – 0.09; participation at seminars and talks: – 0.04; job rotation: – 0.01; self-induced learning: 0.10; quality circles: 0.08; and for 1999: formal external courses: 0.18, formal internal courses: 0.00; training on the job: – 0.12; participation at seminars and talks: – 0.03; job rotation: – 0.10; self-induced learning: 0.05; quality circles: 0.27.

establishments introduce personnel practices that cost time but save money in the long run when they are in economic trouble. Another reason for the increase in training coefficients might be that the measurement error is reduced when the training dummies are estimated by instrumental variables because the measurement error tends to bias the coefficients downwards (Griliches and Hausman, 1986; Zwick, 2003). In any case, not taking into account that training is a choice variable leads to an underestimation of the productivity effects of training. While the estimated productivity impact of training increases after selection correction, the impact of the other explanatory variables on productivity is virtually unchanged.

Time-invariant unobserved heterogeneity bias in the capital and labour coefficients is corrected by using a system GMM estimation approach for the period 1997–2000. This involves a two-step procedure regressing first value-added on the variable inputs capital, labour, and time and industry dummies on the basis of equation (4).[5] Wald tests indicate that time and industry dummies have a significant impact on productivity, while their interactions do not have an impact and are therefore not included in the regression (see Table A.6). The GMM-SYS estimator depends on the absence of second-order serial correlation in the error term (Dearden *et al.*, 2000; Hempell, 2005), while a negative first-order correlation is consistent with the model assumptions. Therefore the serial correlation tests are reported. The Sargan test indicates that the model is not over-identified.

In the next step, the fixed effects are determined by calculating the establishment average residuals between 1997 and 2000 (Black and Lynch, 2001). The establishment fixed effects are explained by the quasi-fixed factors training and the other variables in vector X_i according to equation (5). The panel regressions controlling for unobserved time-invariant heterogeneity lead to similar results as the cross-section estimations (see Table 4): formal external courses and quality circles have a positive significant impact on productivity, while self-induced learning, seminars and talks, as well as job rotation, have no impact. Training on the job has a significant negative impact. The coefficients are between the values of the cross-section estimates for 1998 and 1999 with the exception of training on the job, which has a lower-panel estimation coefficient.

In equation (5), the different training forms are assumed to be exogenous. It has been shown before, however, that training is a decision of the establishment that may be correlated, for example, with the business cycle and therefore with productivity. In order to take unobserved heterogeneity and selectivity into account simultaneously, the selection correction term

5. This estimation suffers from the well-known low capital estimates in regressions on value-added (Griliches and Mairesse, 1998), but the capital coefficient is comparable (albeit less significant) with that found in Black and Lynch (2001); see Table A.6 in the Appendix. In addition, it is – according to expectations – higher than the capital coefficient from a simple fixed-effects estimation (see Table A4 in Zwick, 2002).

Table 4 Two-step panel estimates, dependent variable: average residual 1997–2000

	Equation (5)		Equation (6)	
Exogenous variables	Coefficients	*t*-Values	Coefficients	*t*-Values
Formal external courses	0.185***	5.46	0.282***	5.51
Formal internal courses	0.030	0.89	0.043	1.25
Training on the job	−0.156**	−4.37	−0.126***	−3.56
Seminars and talks	−0.012	−0.38	0.019	0.58
Job rotation	−0.026	−0.60	−0.024	−0.54
Self-induced learning	0.045	1.31	0.047	1.37
Quality circles	0.171***	4.87	0.173***	4.90
Share of qualified employees	0.403***	6.02	0.392***	5.82
Exporter	0.237***	7.03	0.232***	6.95
State-of-the-art technical equipment	0.163***	6.19	0.162***	6.15
Investment in IT	−0.011	−0.34	−0.020	−0.65
Co-determination	0.139***	4.27	0.139***	4.31
Individual establishment	−0.280***	−6.34	−0.281***	−6.42
Partnership	−0.033	−0.80	−0.029	−0.69
Publicly listed company	−0.002	−0.05	−0.002	−0.03
Employee participation	−0.019	−0.68	−0.019	−0.68
Teamwork	−0.056*	−1.87	−0.058*	−1.95
Units with own costs and results accounting	0.010	0.27	−0.005	−0.14
Stringent hiring rules	0.012	0.38	0.006	0.18
Incentive payments	0.087***	2.88	0.087***	2.84
Establishment size 20–199	0.171***	4.00	0.187***	4.34
Establishment size 200–499	0.209***	3.27	0.236***	3.63
Establishment size 500–999	0.370***	5.58	0.409***	6.04
Establishment size 1,000 +	0.410***	6.67	0.451***	6.13
Selection correction term			0.107***	3.17
Constant	−0.208**	−2.04	−0.285***	−2.71
15 sector dummies and East Germany dummy	Yes		Yes	
Number of observations	2,484		2,484	
Adjusted R^2	0.25		0.25	

Notes: All variables pertain to year 1997 except co-determination and the human resource measures that pertain to 1998. ***Significant at 1% level; **at 5% level; *at 10% level; the standard errors are heteroscedasticity-consistent.
Source: IAB Establishment Panel; waves 1997–2001; own calculations.

from (6) is included in the final regression. The measured productivity impacts of all training forms increase again while the largest changes can be found for external formal courses and training on the job. The coefficients of the other explanatory variables are almost unchanged with the exception

of some establishment size dummies (see Table 4). The highly significant selection correction term indicates that selectivity still biases the estimated training effects, although the average productivity differences during the three years after training incidence and a broad range of relevant control variables are used, and unobserved time-invariant heterogeneity in capital and labour is corrected. The sign of the selection correction term implies – such as in the cross-section equations – that especially the establishments with a productivity disadvantage decide to offer training.

Omitted variable bias would again change these results. When the second estimation step in Table 4 is re-calculated according to equation (6) and, besides the training variables, only the East Germany dummy and the sector controls are included, again higher impacts of training on productivity are obtained.[6]

External and internal formal courses, quality circles and self-induced learning all may partly take place off the job and not during working hours, whereas job rotation and on-the-job training are training forms that take place during working hours and on the job. Therefore, our results broadly support those found in the literature: training off the job seems to be more effective in increasing establishment productivity than training on the job (Black and Lynch, 1996). When it is assumed that a quality circle is mainly a discussion and brainstorming forum that induces the employees to share their ideas and experiences, it can be argued that the productivity-increasing training forms contain more general human capital content than the other training forms. This again is in accordance with the previous literature (Barrett and O'Connell, 2001).

6. CONCLUSIONS

This paper shows that the most popular training form – formal external training – yields the highest productivity increase in German establishments. This productivity increase is measurable even two years after training incidence and in the average productivity of the establishments during a three-year period after training. According to the preferred estimation specification in Table 4, formal external training increases average productivity by 28% while quality circles increase productivity by 17%. It has to be taken into account, however, that this is the productivity effect of treatment on the treated. This means that the effect probably is lower for those establishments that decided not to offer these training forms in 1997. Although internal formal training and participation at seminars and talks are also widespread training forms, these continuing vocational training measures do not have a long-lasting positive productivity impact. Training

6. The coefficients in the parsimonious estimation are: formal external courses: 0.32; formal internal courses: 0.07; training on the job: – 0.10; participation at seminars and talks: 0.05; job rotation: – 0.02; self-induced learning: 0.02; quality circles: 0.19.

on the job (and to a lesser extent job rotation) have a negative productivity impact even several years after the training incidence. This disturbing result may come from the fact that most establishments that offer training on the job in 1997 also did so in the following years,[7] and training on-the-job only has a positive effect on productivity some time after training incidence. An additional reason may be that on-the-job training is indicating a high (internal) turnover in the establishments or restructuring. Both measures are positively correlated with on-the-job training and reduce productivity.[8] Finally, some establishments that in fact do not engage in training may indicate that they offer on-the-job training because this presents the establishment in a better light. This study also shows, however, that cost-effective and relatively scarcely used training measures, such as quality circles and to a lesser extent self-induced learning, do have a positive productivity impact. It therefore seems that these measures are still under-utilized in Germany. The positive productivity impact of quality circles is only measurable with a lag of more than one year, however.

Selectivity and unobserved heterogeneity both have an impact on the measurement of the productivity impact of different continuing vocational training forms. Correcting the selectivity of training by adding a selection correction term for the decision of the establishment to offer training increases the measured productivity impact especially for formal external training and training on the job. This implies that establishments which face a temporary productivity gap select training as a measure to fill it. The paper therefore demonstrates that one motivation of establishments to train is to regain competitiveness, because it is a suitable means to reduce productivity gaps. An important proviso for the selectivity correction is, however, that only the decision of the establishment to offer some training or no training could be modelled, because it seemed impossible to disentangle seven different motives to offer the individual training forms. This means that there is no separate selectivity correction for the individual training forms. A second proviso is closely related to this point. Certain training forms (especially training on the job and formal internal and external training) are closely correlated with each other. This might induce some multi-collinearity and reduce the significance levels for the individual training forms affected.

Taking unobserved heterogeneity into account by measuring the variable inputs by panel estimation methods also changes the measured productivity impact of continuing vocational training. After correcting for unobserved heterogeneity and endogeneity of the input factors labour and capital and

7. The share of establishments that offered individual training measures in 1998/99 was between 0.83 and 0.97 of those establishments that offered these training measures already in 1996/97, depending on the measure. On-the-job training was offered by 0.87 of the establishments in both periods.
8. I am grateful to two anonymous referees for pointing out these explanations.

including a broad variety of explanatory variables, the selectivity correction term for the decision of the establishment to offer training is still significant. It can be concluded that estimations that take only selectivity of training or unobserved heterogeneity into account might be plagued by estimation bias. Finally, omitted variable bias is detected. When a broad variety of establishment, employee and personnel management characteristics is not taken into account, the estimated productivity impact of training is too high.

APPENDIX

Table A.1 Descriptive statistics, 1997

Variables	Average	Answers	Comments
Number of employees	3.08	5,428	Number of employees at 1.6.1997, ln
Formal external courses	0.55	5,428	External courses, seminars offered in first half of 1997, Yes/No
Formal internal courses	0.37	5,428	Internal courses, seminars offered in first half of 1997, Yes/No
Training on the job	0.40	5,428	Training on the job (instruction, learning by doing) offered in first half of 1997, Yes/No
Participation at seminars and talks	0.42	5,428	Participation at presentations, seminars, fairs offered in first half of 1997, Yes/No
Job rotation	0.09	5,428	Job rotation offered in 1997, Yes/No
Self-induced learning	0.14	5,428	Self-induced learning on the basis of computer-aided programmes or literature offered in first half of 1997, Yes/No
Quality circles	0.13	5,428	Quality circles, discussion groups, participation groups etc. offered in first half of 1997, Yes/No
Redundancies expected	0.14	5,640	Over the next two years, redundancies are expected, Yes/No
Many employees are expected to be on maternity leave	0.05	5,460	Over the next two years, organizational problems due to maternity leave are expected, Yes/No
High qualification need expected	0.11	5,640	Over the next two years, a large demand for training and qualifications is expected, Yes/No
Apprenticeship training reaction to skill shortages	0.35	5,640	Apprenticeship training highest priority to fill skills gap (in contrast to training and hiring skilled workers)

(Continued)

Table A.1 Continued

Variables	Average	Answers	Comments
Training reaction on skill shortages	0.35	5,640	Training own employees has highest priority to fill skills gap (in contrast to apprenticeship training and hiring skilled employees)
Exporter	0.25	5,602	Establishment exports, Yes/No
Investor in IT	0.65	5,675	Investment in communication or electronic data procession, Yes/No
Share of qualified employees 1997	0.60	5,666	Share of employees with a formal qualification degree on all employees
State-of-the-art technical equipment	0.72	5,450	Technical equipment is marked state-of-the-art in comparison to sector, Yes/No
Establishment size 1–19 (reference)	0.40	5,640	Establishment has 1–19 employees in 1997
Establishment size 20–199	0.40	5,640	Establishment has 20–199 employees in 1997
Establishment size 200–499	0.10	5,640	Establishment has 200–499 employees in 1997
Establishment size 500–999	0.04	5,640	Establishment has 500–999 employees in 1997
Establishment size 1,000 +	0.06	5,640	Establishment has more than 1,000 employees in 1997
Individual establishment	0.25	5,602	Individual establishment, Yes/No
Partnership	0.09	5,603	Partnership, Yes/No
Limited company (reference category)	0.59	5,602	Limited company, Yes/No
Publicly listed company	0.01	5,602	Publicly listed company, Yes/No
Collective wage agreement	0.68	5,640	Establishment is subject to collective wage agreements, Yes/No
Apprenticeship training	0.61	5,640	Establishment offers apprenticeship training, Yes/No

Source: IAB Establishment Panel; wave 1997; representative values.

Table A.2 Descriptive statistics, 1998

Variables	Average	Answers	Comments
Value-added	14.07	4,154	Turnover minus external input costs and costs for third parties, deflated, ln
Capital	11.85	6,221	Proxy: investments minus expansion investments, ln, deflated, from wave 1999
Labour	3.21	6,192	Number of employees at 1.6.1997, ln
Investment in IT	0.66	6,176	Investment in communication or electronic data procession, Yes/No
Share of qualified employees	0.62	6,187	Share of employees with a formal qualification degree on all employees
Exporter	0.22	6,180	Exporter, from wave 1999, Yes/No
State-of-the-art technical equipment	0.75	6,179	Technical equipment is marked state-of-the-art in comparison to sector, Yes/No
Employee participation	0.23	6,079	Establishment shifted responsibility and decisions to lower ranks until 1998, Yes/No
Teamwork	0.16	6,079	Establishment has team work and independent groups in 1998, Yes/No
Units with own costs and results accounting	0.12	6,079	Establishment has units with own costs and results accounting in 1998, Yes/No
Stringent hiring rules	0.27	6,079	Establishment has formal hiring rules in 1998, Yes/No
Incentive payments	0.13	6,079	Establishment has gain sharing or employee share ownership in 1998, Yes/No
Co-determination	0.34	6,170	Establishment has a work council in 1998, Yes/No
Exporter	0.22	6,221	Establishment exports, Yes/No
Individual establishment	0.27	6,221	Individual establishment, Yes/No
Partnership	0.10	6,221	Partnership, Yes/No
Limited company (reference category)	0.51	6,221	Limited company, Yes/No
Publicly listed company	0.06	6,221	Publicly listed company, Yes/No

Source: IAB Establishment Panel; waves 1998 and 1999; own calculations.

Table A.3 Descriptive statistics, 1999

Variables	Average	Answers	Comments
Value-added	14.14	5,969	Turnover minus external input costs and costs for third parties, in DM, ln, deflated, from wave 2000
Capital	13.11	6,854	Proxy: investments minus expansion investments, in DM, ln, deflated, from wave 2000
Labour	3.17	6,670	Number of employees at 1.6.1999, ln
Investment in IT	0.87	6,886	Investment in communication or electronic data procession, Yes/No
Share of qualified employees	0.69	6,886	Share of employees with a formal qualification degree on all employees
Exporter	0.26	6,886	Exporter, Yes/No
Co-determination	0.36	6,701	Establishment has a work council in 1999, Yes/No
State-of-the-art technical equipment	0.75	5,450	Technical equipment is marked state-of-the-art in comparison to sector, Yes/No
Collective wage agreements	0.68	6,701	Establishment is subject to collective wage agreements, Yes/No
Individual establishment	0.27	6,701	Individual establishment, Yes/No
Partnership	0.10	6,701	Partnership, Yes/No
Limited company (reference category)	0.51	6,701	Limited company, Yes/No
Publicly listed company	0.06	6,701	Publicly listed company, Yes/No

Source: IAB Establishment Panel; waves 1999 and 2000; own calculations.

Table A.4 Descriptive statistics, 2000

Variables	Average	Answers	Comments
Value-added	14.25	8,892	Turnover minus external input costs and costs for third parties, in DM, ln, deflated, from wave 2001
Capital	11.83	7,054	Proxy: investments minus expansion investments, in DM, ln, deflated, from wave 2001
Labour	3.14	10,013	Number of employees at 1.6.2000, ln

Source: IAB Establishment Panel; waves 2000 and 2001; own calculations.

Table A.5 Correlation coefficients between different training forms

Training forms	Formal external training	Formal internal training	Training on the job	Seminars and talks	Job rotation	Self-induced training	Quality circles
Formal external training	1						
Formal internal training	0.31	1					
Training on the job	0.48	0.50	1				
Seminars and talks	0.56	0.37	0.47	1			
Job rotation	0.11	0.22	0.21	0.11	1		
Self-induced learning	0.28	0.29	0.40	0.36	0.14	1	
Quality circles	0.13	0.26	0.22	0.22	0.21	0.17	1

Source: IAB Establishment Panel; wave 1997; own calculations.

Table A.6 System GMM productivity estimation, value-added 1997–2000, two-step estimates, equation (4)

	Coefficients	*z*-Values
Capital	0.100	0.82
Labour	1.067***	5.98
Constant	9.28***	8.10
Three time and 14 industry dummies	Yes	
Number of observations	2,955	
Number of establishments	846	
Wald test of joint significance	81.62 (df = 2)	$p = 0.00$
Wald test of time and industry dummies	92.41 (df = 17)	$p = 0.00$
Sargan test	10.85 (df = 8)	$p = 0.21$
Test for first-order serial correlation	− 4.79	$p = 0.00$
Test for second-order serial correlation	− 1.06	$p = 0.29$

Note: The standard errors are heteroscedasticity-corrected.
Source: IAB Establishment Panel; waves 1997–2001; own calculations.

ACKNOWLEDGEMENTS

This paper was mainly written during my stay at the Centre on Skills, Knowledge and Organisational Performance (SKOPE) in Oxford. I want to

thank Bernd Fitzenberger, Thomas Hempell, Kornelius Kraft, Johannes Ludsteck, Ken Mayhew, Guy Vernon, Elke Wolf, Andreas Ziegler and two anonymous referees for helpful comments and suggestions. In addition, I am grateful to the Institut für Arbeitsmarkt- und Berufsforschung (IAB) and especially Holger Alda for being helpful with the access to the IAB Betriebspanel.

Address for correspondence: Centre for European Economic Research (ZEW), L7, 1, 68161 Mannheim, Germany. Tel.: + 49-621-1235283; fax: + 49-621-1235225; e-mail: zwick@zew.de

REFERENCES

Acemoglu, D. and J.-S. Pischke (1999), 'Beyond Becker: Training in Imperfect Labour Markets', *Economic Journal* 109, 112–143.

Appelbaum, E. and R. Batt (1994), *The New American Workplace: Transforming Work Systems in the United States*, ILR Press, New York.

Arellano, M. and S. Bond (1998), 'Dynamic Panel Data Estimation Using DPD98 for GAUSS: A Guide for Users', mimeo, Institute for Fiscal Studies, London.

Arellano, M. and O. Bover (1995), 'Another Look at the Instrumental Variable Estimation of Error-Components Models', *Journal of Econometrics* 68, 29–51.

Ballot, G., F. Fakhfakh and E. Taymaz (2001), 'Firms' Human Capital, R&D and Performance: A Study on French and Swedish Firms', *Labour Economics* 8, 443–462.

Barrett, A. and P. O'Connell (2001), 'Does Training Generally Work? The Returns to In-Company Training', *Industrial and Labour Relations Review* 54, 647–662.

Bartel, A. (1994), 'Productivity Gains from the Implementation of Employee Training Programs', *Industrial Relations* 33, 411–425.

Bartel, A. (1995), 'Training, Wage Growth, and Job Performance: Evidence from a Company Database', *Journal of Labor Economics* 13, 401–425.

Bartel, A. (2000), 'Measuring the Employer's Return on Investments in Training: Evidence from the Literature', *Industrial Relations* 39, 502–524.

Bassi, L., P. Harrison, J. Ludwig and D. McMurrer (2001), 'Human Capital Investments and Firm Performance', mimeo, Human Capital Dynamics, Bethesda.

Bellmann, L. and F. Büchel (2001), 'Betrieblich finanzierte Weiterbildung und Unternehmenserfolg', in: U. Backes-Gellner and P. Moog (eds.), *Bildungssystem und betriebliche Beschäftigungsstrategien*, Duncker-Humblot, Berlin.

Berg, P. (1994), 'Strategic Adjustments in Training: A Comparative Analysis of the US and German Automobile Industries', in: L. Lynch (ed.), *Training and the Private Sector: International Comparison*, University of Chicago Press, Chicago.

Black, S. and L. Lynch (1996), 'Human Capital Investments and Productivity', *American Economic Review (Papers & Proceedings)* 86, 263–267.

Black, S. and L. Lynch (2001), 'How to Compete: The Impact of Workplace Practices and Information Technology on Productivity', *Review of Economics and Statistics* 83, 434–445.

Blundell, R. and S. Bond (1999), 'GMM Estimation with Persistent Panel Data: An Application to Production Functions', IFS Working Paper No. 99/4, London.

Caroli, E. and J. van Reenen (2001), 'Skill-Biased Organizational Change? Evidence from a Panel of British and French Establishments', *Quarterly Journal of Economics* 116, 1449–1492.
Dearden, L., H. Reed and J. van Reenen (2000), 'Who Gains When Workers Train? Training and Corporate Productivity in a Panel of British Industries', IFS Working Paper No. 00/01, London.
Düll, H. and L. Bellmann (1998), 'Betriebliche Weiterbildungsaktivitäten in West- und Ostdeutschland', *Mitteilungen aus der Arbeitsmarkt- und Berufsforschung* 31, 205–225.
Gerlach, K. and U. Jirjahn (2001), 'Employer Provided Further Training: Evidence from German Establishment Data', *Schmollers Jahrbuch* 121, 139–164.
Greene, W. (2000), *Econometric Analysis*, 4th edn, Prentice-Hall, Upper Saddle River, NJ.
Griliches, Z. and J. Hausman (1986), 'Errors in Variables in Panel Data', *Journal of Econometrics* 31, 93–118.
Griliches, Z. and J. Mairesse (1998), 'Production Functions: The Search for Identification', in: S. Strøm (ed.), *Econometrics and Economic Theory in the 20th Century*, Cambridge University Press, Cambridge.
Hall, B. and J. Mairesse (1995), 'Exploring the Relationship between R&D and Productivity in French Manufacturing Firms', *Journal of Econometrics* 65, 263–293.
Heckman, J. (1976), 'The Common Structure of Statistical Models of Truncation, Sample Selection and Limited Dependent Variables and a Simple Estimator for Such Models', *Annals of Economic Social Measurement* 5, 475–492.
Hempell, T. (2005), 'What's Spurious, What's Real? Measuring the Productivity Impacts of ICT at the Firm-Level', *Empirical Economics*, forthcoming.
Ichniowski, C., K. Shaw and G. Prennushi (1997), 'The Effects of Human Resource Management Practices on Productivity', *American Economic Review* 87, 291–313.
Institut der deutschen Wirtschaft (2002), *Deutschland in Zahlen*, Köln.
Kölling, A. (2000), 'The IAB Establishment Panel', *Schmollers Jahrbuch* 120, 291–300.
Koning, J. de (1994), 'Evaluating Training at the Company Level', in: R. McNabb and K. Whitfield (eds.), *The Market for Training*, Avebury, Aldershot.
Kruse, D. (1993), *Profit Sharing: Does it Make a Difference?*, Upjohn Institute, Kalamazoo, MI.
Lynch, L. and S. Black (1998), 'Beyond the Incidence of Employer-Provided Training', *Industrial and Labor Relations Review* 52, 64–81.
Maddala, G. (1983), *Limited-Dependent and Qualitative Variables in Econometrics*, Cambridge University Press, Cambridge.
Nickell, S., D. Nicolitsas and M. Patterson (2001), 'Does Doing Badly Encourage Management Innovation?', *Oxford Bulletin of Economics and Statistics* 63, 5–28.
Roth, S. (1997), 'Germany: Labor's Perspective on Lean Production', in: T. Kochan, R. Lansbury and J. MacDuffie (eds.), *After Lean Production*, ILR Press, Ithaca, NY.
Statistisches Bundesamt (2001), *Statistical Yearbook for the Federal Republic of Germany*, Schaeffer-Pöschel, Stuttgart.
Whitfield, K. (2000), 'High-Performance Workplaces, Training, and the Distribution of Skills', *Industrial Relations* 39, 1–25.
Wolf, E. and T. Zwick (2002), 'Produktivitätswirkung von Mitarbeiterbeteiligung: Der Einfluss von unbeobachteter Heterogenität', *Mitteilungen aus der Arbeitsmarkt- und Berufsforschung* 35, 123–132.

Wolf, E. and T. Zwick (2003), 'Welche Personalmaßnahmen entfalten eine Produktivitätswirkung?', *Zeitschrift für Betriebswirtschaft* 73, EH 4/2003, 43–62.
Zwick, T. (2002), 'Continuous Training and Firm Productivity in Germany', ZEW Discussion Paper No. 02-50, Mannheim.
Zwick, T. (2003), 'The Impact of ICT Investment on Establishment Productivity', *National Institute Economic Review* 184, 99–110.
Zwick, T. (2004a), 'Training – A Strategic Enterprise Decision?', in: G. Fandel, U. Backes-Gellner, M. Schlüter and J. Staufenbiel (eds.), *Modern Concepts of the Theory of the Firm – Managing Enterprises of the New Economy*, Springer-Verlag, Heidelberg, pp. 355–366.
Zwick, T. (2004b), 'Employee Participation and Productivity', *Labour Economics* 11, 715–740.
Zwick, T. and H. Schröder (2001), *Wie aktuell ist die Berufsbildung im Dienstleistungssektor?*, Nomos, Baden-Baden.