The Impact of Training Intensity on Establishment Productivity

Dr. Thomas Zwick*

Centre for European Economic Research (ZEW)

P.O. Box 103443

D-68034 Mannheim, Germany

Tel.: ++49-621-1235283

E-mail: zwick@zew.de

* This paper was mainly written during my research stay at the Centre on Skills, Knowledge and Organisational Performance (SKOPE), University of Oxford. I am grateful to Thomas Hempell, Johannes Ludsteck, Ken Mayhew, Guy Vernon, Elke Wolf, Andreas Ziegler, and David Levine for their helpful comments. I thank the Institute for Employment Research (IAB), Nuremberg for granting me access to the IAB establishment panel. Data processing by the Research Data Centre (FDZ) of the Federal Employment Services (BA) at the IAB, Nuremberg. The institutions mentioned are not responsible for the use of the data in this publication.

Abstract

This paper measures the impact of training intensity on establishment productivity in a production function using the representative German IAB establishment panel set. An increase in the share of trained employees in the first half of 1997 by one percent significantly increases average value added in the period 1998 – 2001 by more than 0.7%. The estimation method chosen simultaneously corrects for unobserved time-invariant heterogeneity of establishments, using a fixed effects panel regression, and for selectivity of training by instrumenting the training intensity variable. In addition, the estimation includes a broad variety of control variables for establishment and employee characteristics as well as several personnel management measures in order to reduce omitted variable bias. This innovative approach demonstrates that the estimation results are sensitive to the three sources of estimation bias. Selectivity leads to an underestimation, while omitted variable bias leads to an overestimation of the productivity effect of training intensity.

JEL Codes: C23, D21, J24

Key Words: Training, Firm Productivity, Panel Estimation

Introduction

The empirical literature on productivity effects of continuing training is constantly increasing. However, the results on this subject differ widely. Explanations for this worrying diversity seem to lie in differences between countries, labor market institutions and data generation on one hand, and in differences between the underlying estimation techniques on the other hand (Bartel, 2000). This paper concentrates on the latter problem and shows how results vary with different estimation techniques.

The central estimation problem is endogeneity of continuing training and other production inputs such as labor and capital. Firms do not decide randomly how many employees need to be trained, and therefore training is not a strictly exogenous variable in the productivity equation. The decision to increase or decrease other input factors is also inseparably linked to fluctuations in output and productive efficiency influenced by unobservable elements. The endogeneity problem may therefore be the source of two distinct biases (Kruse, 1993; Dearden, Reed and Van Reenen, 2000; Black and Lynch, 2001; Caroli and Van Reenen, 2001). First, firms that offer training may be structurally more or less productive due to time-invariant unobserved factors such as management quality, the exposition to long-term technical change, personnel department activity, or management-employee relations. This source of estimation bias is called unobserved time-invariant heterogeneity. Second, transitory shocks, such as the introduction of a new technology or a change in product or labor market conditions, could change output and input decisions and induce changes in training efforts at the same time. This source of estimation bias is called endogeneity bias of training intensity. Omitted variables also lead to estimation bias. The training measure may pick up productivity effects of other relevant variables, such as personnel management methods or the qualification level of the workforce. Although those are closely related to the training behavior and productivity of the firm, they are frequently not taken account of in the estimation (Ichniowski, Shaw and Prennushi, 1997; Dearden, Reed and Van Reenen, 2000; Zwick, 2004b).

The main contribution of this paper is to simultaneously address all three potential sources of estimation bias at once while estimating the productivity impact of the share of trained employees divided by the total number of employees. For that purpose, a standard panel production function estimation on the basis of representative German establishment data is used. Additionally an innovative two-step instrumental variable and panel estimation technique is employed. A broad range of establishment and employee characteristics is taken into account. By comparing the estimation results obtained by this approach with the uncorrected OLS estimates, the paper reveals the sign and the size of the sources of estimation bias mentioned above.

Literature

Human capital, knowledge, and skills are increasingly important competitive assets within firms. The investments in continuing training are considerable: On the basis of answers from 550 enterprises originating from 42 countries worldwide, the American Society for Training and Development (ASTD) reports that in 2000 the share of training expenditures on pay-roll was on average 2% in the USA and 2.5% in Europe (Marquardt, King and Ershkine, 2002). Although continuing training plays a central role in firm's skill provision and competitiveness, the evidence on its productivity effects is thin and partly contradictory. A growing number of papers tries to capture the effect of employer-provided training on productivity by using representative firm-level data from several sectors in the economy. The estimation results vary strongly, however, depending on the estimation technique used. In this section, a short survey of studies that use firm- or establishment-level data from several economic sectors is provided. Focusing on the data and the estimation techniques used, their possible shortcomings are highlighted.

In one of the first contributions to this topic, Holzer et al. (1993) estimate the effect of training on the scrap rate. The data consist of 390 applicants for the Michigan Job Opportunity Bank-Upgrade between 1987 and 1989. The authors estimate the variables in differences in order to avoid unobserved heterogeneity bias and include indicators for industrial relations and reasons for training. They find that a change in the annual hours of training per employee has a significant and substantial positive impact on product quality. This effect vanishes, however, when lagged changes in training are added.

Bartel (1994) first estimates a simple cross-section production function including a dummy for formal training programs in the effective labor term. She does not find an effect of formal training on productivity in the same year. The estimation may be biased, however, because unobserved heterogeneity between firms leads to a correlation between the formal training measure and the error term (Griliches and Mairesse, 1998). In order to avoid this bias, she estimates a first difference model where the change in labor productivity between 1983 and 1986 is regressed on changes in the incidence of training programs. This change in the estimation method increases the measured productivity impact of training. She finds that businesses operating below their expected labor productivity levels in 1983 implemented new employee training programs afterwards. That brought productivity up to the level of comparable businesses by 1986.

Barrett and O'Connell (2001) apply the same estimation strategy, but they regress the level of training intensity on the change in productivity instead of the change in training intensity. They use data from two waves of Irish firms surveyed in 1993 and 1995, where the response rate of the second wave was as low as one-third of the initial firms. The effect of training days/total employment is positive and significant on changes in labor productivity, while the inclusion of several personnel management measures does not have an impact on the training coefficient. The studies by Bartel and Barrett and O'Connell do not address selectivity of the introduction of training programs, and they are based on probably rather specific samples (Dearden, Reed and Van Reenen, 2000).

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 data set from the 1994 US-American National Center on the Educational Quality of the Workforce (EQW). They find no impact of the share of trained employees on sales, while a high percentage of formal training outside working hours has a positive impact on productivity in manufacturing and computer training has a positive impact on productivity in non-manufacturing. However, their cross-section study is prone to unobserved heterogeneity bias, and they take training as an exogenous variable in their regression.

In order to correct for unobserved time-invariant heterogeneity between firms, Black and Lynch (2001) supplement their data on training and other workplace practices with panel data from the Longitudinal Research Database (LRD). In the first estimation step, they calculate the average firm-specific, time-invariant residual in a fixed effects Cobb-Douglas production function without the almost time-invariant workplace practices, training methods and other firm and employee characteristics. In a second step, they regress the average establishment residual on training and the other quasi-fixed factors. In this regression, training intensity has still no impact on productivity, irrespective of whether unobserved time-invariant heterogeneity is corrected for or not. Black and Lynch (2001: 443) admit that their estimation techniques only correct for endogeneity in the time-variant parameters included in the first step while the second step estimates (including training intensity) are prone to selectivity bias.

Ballot, Fakhfakh and Taymaz (2001) find that the impact of training hours per employee on firm productivity depends strongly on the underlying estimation technique. In their preferred specification, a system GMM estimation takes account of possible endogeneity of labor, capital, training, and R&D in the productivity estimation. They find that training has a positive and significant impact on value added in France, while in Sweden the effect is insignificant. Their instruments (values of the explanatory variables lagged by one or two years) may be weak because all instrumented variables and the dependent variable may be affected by shocks that take longer than one or two years (Dearden, Reed and Van Reenen, 2000). Their panel includes six years and is too short for designing longer lags. In addition, their specification is very parsimonious and takes only tangible assets and their interactions into account, while further firm and personnel characteristics are absent. Finally, their sample size of 90 firms in France and 270 firms in Sweden is small and specific.

Bassi et al. (2001) correlate training expenditures with indicators for the firm performance a year later. They find that training expenditures have no correlation with total sales per employee and a negative impact on income and profits in the next year. The long-run impact of training on firm´s profitability as captured by changes in Tobin´s Q and share prices is positive. They even measure a super-normally high rate of return – one dollar invested in training gives more than 33$ in benefits to the firm – and this leads the authors to conclude that firms are under-investing in training. As they use only a very limited set of additional control variables, Bassi et al. mention that training may serve as a marker for other unmeasured firm-level attributes that are correlated with a firm's long-term profitability. In other words, the estimation might suffer from omitted variable bias.

Dearden, Reed and Van Reenen (2000) present a study on the productivity impact of training intensity on the industry level in Great Britain. They use a long panel data set between 1983 and 1996 that entails information on training in every year. They address unobserved heterogeneity as well as selectivity of training simultaneously by using a system GMM estimation including levels, first differences and lags of capital, labor as well as training intensity (Blundell and Bond, 1999). In addition, they calculate the impact and the sign of the biases incurred when training is taken as exogenous in the estimation. They find a positive and significant effect of training intensity on sector productivity which increases significantly when endogeneity of training is considered. Still, several drawbacks of their approach, have to be mentioned. They combine data on different aggregation levels which may lead to aggregation bias. Lagged variables might be weak instruments for current levels of training intensity, capital and labor (Griliches and Mairesse, 1998). The absence of controls for additional personnel management measures might incur omitted variable bias. Finally, their information on training covers only four weeks per year, and service firms have been dropped due to "measurement problems" in most regressions.

Summing up the literature survey, most studies on the firm or establishment level find a positive (although frequently insignificant) impact of training intensity on productivity, but are plagued by estimation or data problems.

Derivation of the Empirical Models

Analogous to the previous literature, we assume a standard Cobb-Douglas production function. Output Y_i of establishment i is a function of capital K_i and "effective labor" L_i weighted by the number of trained employees (Dearden, Reed and Van Reenen, 2000):

$$(1) \qquad Y_i = A_i * K_i^{b} * L_i^{g} \qquad \text{with } L = N_{Ui} + t\, N_{Ti} ,$$

where A_i is a Hicks neutral efficiency parameter, N_{Ui} is the number of untrained and N_{Ti} the number of trained employees. The parameter t is larger than one if training has a positive effect on labor productivity.

Equation (1) can be re-written as:

$$(2) \qquad Y_i = A_i * K_i^{b} * N_i^{g} (1 + (t - 1)T_i)^{g} ,$$

where $N_i = N_{Ti} + N_{Ui}$ is the number of employees and $T_i = N_{Ti}/N_i$ is the proportion of trained workers in an establishment (or training intensity). If we take logs and use the approximation $\ln(1+x) = x$ for small x (Dearden, Reed and Van Reenen, 2000), we get:

$$(3) \qquad \ln Y_i = \ln A_i + b \ln K_i + g \ln N_i + g(t-1)T_i + e_i .$$

Our hypothesis is that trained employees are more productive than untrained employees. In other words, $g(t-1)$ is larger than zero, which means that increasing the training intensity has a positive impact on the establishment productivity.

Empirically, many further factors in addition to capital, labor and training intensity are relevant for establishment productivity. In order to avoid omitted variable bias, this paper considers a large vector of further explanatory variables. In particular, other dimensions of worker heterogeneity, such as the share of qualified employees, and establishment heterogeneity, such as the state of technical equipment, as well as a dummy for establishments investing in information technology (IT), co-determined or exporting establishments are included (also compare Dearden, Reed and Van Reenen, 2000; Black and Lynch, 2001).

Training measures are closely correlated with other innovative personnel measures that increase the participation of employees and are usually labeled “high performance workplaces” (Whitfield, 2000; Barrett and O’Connell, 2001; Wolf and Zwick, 2002). Indeed, higher participation of employees might increase the inclination of employees to take training. On the other hand, new workplace practices might also increase the necessity of training, especially when they require increased flexibility and a higher grade of discretion from non-managerial employees. Whitfield (2000) demonstrates that the average number of training days per employee is positively correlated with the introduction of participative personnel measures. Wolf and Zwick (2002) also find a high joint incidence of training and participative workplace organizations. In order to avoid that the training variable picks up productivity effects from high performance workplace practices, a couple of crucial additional controls for relevant innovative personnel measures are added to the production function in equation (3): more responsibilities for non-managers, teamwork, groups with cost responsibility, strong selection procedures when hiring new employees, employee share ownership, and profit sharing.

In order to estimate equation (3), a vector V_i entailing the variables described above is added. As many empirical assessments of the productivity effect of training use parsimonious specifications similar to (3), estimation results excluding further control variables are also reported. This reveals the size of the omitted variable bias for the data used.

Fixed Effects Estimation

Cross-section production function estimations may be biased because explanatory variables (for example capital and labor) are endogenous (Griliches and Mairesse, 1998; Blundell and Bond, 1999). Endogeneity of explanatory variables can result in biased cross-section estimates. The reason is that unobserved factors, such as management quality, industrial relations, or technological change, have an impact on the explanatory variables and on value added at the same time (Huselid and Becker, 1996). These factors are frequently rather stable over a period of several years. A possibility to correct for biases caused by unobserved time-invariant establishment-specifics is to use panel estimation methods that eliminate the establishment fixed effects. Taking, for example, the deviations from an establishment's mean or first differences of equation (3) in a fixed effects estimation, all time-invariant fixed effects drop out. However, that way the impact of observed time-invariant effects cannot be taken into account. Between two years, the training intensity and most other employee and establishment characteristics in vector V_i do not change much and therefore the ratio between signal and noise is low if training intensity and other quasi-fixed variables are included into a fixed effects estimator (Dearden, Reed and Van Reenen, 2000). Our observation period is only five years long and information on several explanatory variables is not available in every year. Therefore, not all variables can be included in a fixed effects estimation 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 labor – as well as time and industry dummies is estimated (in order to control for differences between sectors and during the business cycle) using panel estimation techniques that incorporate unobserved time-invariant heterogeneity. From this estimation, the establishment-specific, time-invariant component of the residual is calculated. This residual intuitively indicates if total factor productivity of an establishment is higher or lower than that of its competitors with comparable variable inputs and within the same economic sector. In a second step, the average establishment fixed effect is regressed on the quasi-fixed explanatory variables in V_i and training intensity T_i.

For the first step estimation, a within estimator is used that allows the calculation of an establishment fixed effect from the panel data (compare also Black and Lynch, 2001).[i] In order to allow a more flexible production function, a translog specification instead of the Cobb-Douglas specification was tested. Since capital-square, labor-square and the interaction term between labor and capital are jointly significant, this specification is preferred.[ii] The first step of the panel regression can therefore be written as:

$$\text{(4)} \qquad \ln Y_{t,i} = \ln A_{t,i} + \boldsymbol{a} \ln K_{t,i} + \boldsymbol{b} \ln\left(K_{t,i}^2\right) + \boldsymbol{g} \ln N_{t,i} + \boldsymbol{d} \ln\left(N_{t,i}^2\right) + \boldsymbol{f} \ln\left(K_{t,i} * N_{t,i}\right) + \boldsymbol{n}_i + \boldsymbol{e}_{t,i},$$

with $\boldsymbol{n}_i$ the time-invariant establishment fixed effect, $\boldsymbol{e}_{it}$ the idiosyncratic component of the error term, and t a year indicator. The fixed effect is the average establishment-specific difference from expected productivity on the basis of inputs. This time-invariant variable therefore measures whether total factor productivity was structurally below or above that of the other establishments. It serves as dependent variable for the second estimation step.

In the second step, the quasi-fixed variables, such as training intensity, establishment characteristics, and personnel measures explain the establishment fixed effect:

$$(5) \qquad n_i = m' V_{t,i} + k(t-1) T_{t,i} + z_{t,i} \; .$$

An instantaneous effect of training on productivity cannot be expected and employees may actually be less productive during the training period (Bartel, 1995; Dearden, Reed and Van Reenen, 2000; Bassi et al., 2001). Therefore, training intensity and other covariates are measured before the fixed effects period.

Instrumental Variables Approach

The two-step panel procedure addresses biases that may arise in the estimation of the coefficients of capital and labor on value added. It does not address biases in the second estimation step, however. These biases may stem from correlations between the second stage regressors and unobserved establishment characteristics or with idiosyncratic shocks (Black and Lynch, 2001). An establishment’s decision on training intensity may be related to its business performance or to the establishment specific position in the business cycle. Therefore, empirical results of the estimated fixed effects productivity function (5) may be biased because establishments do not randomly decide how many employees to train. Investment in training is an endogenous decision of the establishment instead, which depends on the productivity effects, the investment costs of training and other factors (Dearden, Reed and Van Reenen, 2000; Caroli and Van Reenen, 2001; Bellmann and Büchel, 2001). As a consequence, the impact of training intensity on productivity can be interpreted as a treatment effect with an endogenous choice of the treatment (Maddala, 1983; Greene, 2000).

If the decision of the establishment on how many employees to train is not truly exogenous, the training intensity variable in equation (5) has to be instrumented in order to make it exogenous in the production function. 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 the decision on how many employees should be trained. When establishments expect skill gaps in the future because some employees will be redundant in the near future or the demand for skills increases in general, they may be induced to introduce training now. It can be shown that productivity in the following years is not affected by the expectations on skill gaps: the instruments are neither individually nor jointly significant when included in equation (5). This means that there is no strong correlation between expected skill gaps over time or between expected and actual skill gaps. Moreover, the preferred reaction of the establishment (i.e. mainly the personnel department) on skill shortages has the same statistical properties. When the establishment mainly reacts on skill gaps by additional apprenticeship training or by continuing training of the employees (instead of giving priority to hiring skilled employees from the labor market), the probability that the establishment chooses a high training intensity is increased. It does not have an impact on productivity, however.

Empirically, the decision on training intensity can be described as a reduced form in the following model: The latent training intensity $T^*_{t,i}$ is the optimal share of trained employees in period t and can be defined as:

(6) $$T^*_{t,i} = q\text{'}Z_{t,i} + u_{t,i},$$

where $Z_{t,i}$ is a vector of relevant variables for the training intensity decision of the establishment. For the observable training intensity $T_{t,i}$, we obtain: $T_{t,i}=1$ if $T^*_{t,i}>1$, $T_{t,i}=0$, if $T^*_{t,i}<0$, and $T_{t,i}= T^*_{t,i}$, if $0£T^*_{t,i}£1$.

In the preferred estimation version, an instrumental variable approach is used that first estimates the training intensity decision $\widehat{T^*_{t,i}}$ using several exclusion restrictions according to equation (6) and then estimates the fixed effects productivity function including the predicted training intensity values:

(7) $$n_i = m\tilde{V}_{t,i} + k(t-1)\hat{T}_{t,i} + z_{t,i}\ .$$

The Data

The empirical analysis of the impact of training intensity on establishment productivity is calculated on the basis of the IAB establishment panel (for detailed information see Kölling, 2000 and Bellmann and Büchel, 2001). The IAB establishment panel is collected by personal interviews with the owners or senior managers of smaller and the personnel managers in larger establishments. Specially trained professional interviewers from a well-known market research institute conduct the interviews. As far as possible, the survey is carried out by the same interviewer and interviewee each year. This procedure helps to reduce panel attrition to less than 20% per year. In order to keep the panel representative and to correct for panel mortality, exits and newly-founded units, additional establishments are included each year, yielding an unbalanced panel. The additional establishments are stratified with respect to ten categories of establishment size and 16 economic sectors. The establishments are first approached by a letter indicating the goals of the survey. This letter is accompanied by separate letters of recommendation by the president of the Federal Employment Services and the president of the German Employers' Association. Some weeks after the announcement, the establishment is contacted by telephone in order to arrange an individual appointment for the interview. This procedure ensures a response rate above 70%, which is high compared with other non-official German establishment panel studies (Kölling, 2000).

The sample unit is the establishment as the local business unit. The establishments are selected from a parent sample of all German establishments that employ at least one employee covered by social security. Thus, self-employed and establishments that employ only people not covered by social security (mineworkers, farmers, artists, journalists, etc.) as well as public employers with solely civil servants do not belong to the original sample. In 1997, there are

8.917 establishments included in the raw data, in 1998 there are 10.284, in 1999 11.141, in 2000 15.526, and in 2001 15.537 establishments.

There is a large set of questions that is asked every year on production, investment strategy, industry sector, employee structure, personnel problems, business strategy, and vocational training. 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. Every year, additional questions are added on an irregular basis. In the wave 1997, detailed information on the training behavior of the establishments was collected. In 1998, detailed information on personnel management measures was made available.

Training intensity is measured by the number of employees trained in the first half of 1997 divided by the number of employees in the establishment on June 1st, 1997.[iii] A drawback of this metric is that it does not take into account the intensity or length of the training course employees participated in. Unfortunately, we do not have training expenditures that could reflect these differences. Continuing training intensity does not include the number of apprentices. Establishment productivity is measured by value added. This measure is constructed from sales minus costs for purchased materials and services (for example marketing, insurance and banking costs, travel expenses, legal and consulting costs, postage, and contributions for professional associations rent, raw materials, insurance premia, travel costs, license costs, etc.) and is depreciated by the product price index for different sectors. Capital is not directly measured in the data set and therefore approximated by the perpetual inventory method (Black and Lynch, 2001; Hempell, 2004; Zwick, 2004a). The book value of the capital stock is calculated for 1998 (or for the first year in which an establishment is observed after 1998) by dividing replacement investments by the sum of the (assumed) average depreciation rate and the average growth rate of investments. From the capital stock in the basis year, the capital stock in each following year is calculated by adding deflated expansion investments from the previous period.[iv] Investments are deflated by the input price index of the German Federal Statistical Office (Statistisches Bundesamt, 2001). Descriptive statistics of the data used can be found in tables A1 – A5 in the appendix.

Results

The training decision of the establishment

About one-third of the establishments in Germany does not invest in continuing employee training at all and copes with qualification demands by other measures. In 1997, about 64% of the commercial establishments offered training for their employees while on average 20% of the workforce in these establishments participated in continuing training (see table A1 in the appendix).

This paper concentrates on the influence of training intensity in the first half of 1997 on productivity in the years 1998-2001. Although the lagged training intensity variable is used, a Durbin-Wu-Hausman test shows that training intensity is endogenous in equation (5). Using the four instrumental variables described below, the Durbin-Wu-Hausman test for endogeneity of training intensity is highly significant with $F(1,2081) = 12.04$, $Prob > F < 0.01$. The endogeneity test in a regression estimated via instrumental variables (IV) tests the null hypothesis that an ordinary least squares (OLS) estimator of the same equation would yield consistent estimates: that is, any endogeneity among the regressors would not have deleterious effects on OLS estimates. A rejection of the null hypothesis indicates that endogenous regressors' effects on the estimates are meaningful, and instrumental variable techniques are required (also compare Cappelli, 2004). Therefore, in this section, the establishment’s decision on training intensity in 1997 is estimated according to equation (6). In order to effectively control for selectivity in the productivity estimation presented in the next section, external identifying variables[v] have to be found that exert a significant influence on training intensity but not on productivity when conditioning on actual training as in equation (5) (compare Bartel, 2000 and Dearden, Reed and Van Reenen, 2000).

In addition to the identifying variables, the usual explanatory variables for the determination of the chosen training intensity such as the establishment size, the share of qualified employees, dummies for investors in information and communication (ICT) technology, state-of-the-art technical equipment, establishments with collective wage agreements, co-determination, apprenticeship training, sectors, several personnel management methods, 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; Bresnahan, Brynjolfsson and Hitt, 2002; Böheim and Booth, 2004). These variables are also included in the estimation of the average productivity according to equation (5).

The equation predicting training intensity (see table 1) shows that most German establishments react on skill shortages by additional training efforts because the external skilled labor market is narrow (Roth, 1997; Zwick, 2004b). Therefore, it is not surprising that establishments step up training when they expect a high qualification demand. It could also be anticipated that establishments that give a higher priority to additional apprenticeship training and continuing training efforts instead of hiring skilled employees when they have vacancies for skilled jobs are more prone to offer continuing training for many employees. We also find that apprenticeship training and state-of-the-art technical equipment induce training needs (Düll and Bellmann, 1998; Dearden, Reed and Van Reenen, 2000; Gerlach and Jirjahn, 2001). Collective wage agreements also frequently entail fringe benefits such as training (Böheim and Booth, 2004; Zwick, 2004a). The higher the qualification level of the employees the higher is their training need, and therefore establishments with a larger share of qualified employees tend to train more. It is found that establishments with more than 20 employees train less intensively than establishments with less than 20 employees (not shown in table 1). This finding is not in accordance with the argument that large establishments usually train a higher percentage of employees because they frequently have an own training department and can spread fixed training costs over a larger pool of employees (Lynch and Black, 1998). The East Germany dummy and the sector dummies are jointly significant. In comparison with the banking sector – which is the reference sector – agriculture, the consumption goods industry, retail and wholesale trade and interestingly also the educational establishments offer significantly less training, while establishments in the insurance sector and business services offer more training (not reported in table 1). These correlations have been empirically found for German establishments, for example, by Düll and Bellmann (1998), Bellmann and Büchel (2001), Gerlach and Jirjahn (2001), and Zwick (2004b).

Estimation of the Productivity Effects of Training Intensity

In this section, the productivity effects of increasing continuing training intensity are measured. Time-invariant unobserved heterogeneity is controlled for in the fixed effects panel regression over the period 1998 - 2001. This involves a two-step procedure. In the first step, value added is regressed on the variable input factors capital, labor and time dummies in a fixed effects estimation on the basis of equation (4). The translog specification is preferred over the Cobb-Douglas specification because labor-square, capital-square and labor*capital are jointly highly significant.[vi] The within estimator produces implausibly low capital coefficients and returns to scale[vii], presumably because measurement errors in the explanatory variables bias the coefficients towards zero. In addition, the lagged levels of capital or labor 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). Then the fixed effects $?_i$ are determined by calculating the average error terms per establishment during the estimation period (Black and Lynch, 2001).

In the second estimation step, the fixed effects are regressed on the quasi-fixed factors training intensity and the other variables in V_i.[viii] These additional explanatory variables are: 15 sector dummies and a dummy for East German establishments that capture the differences in productivity between the sectors and the productivity gap of East German establishments. Qualified employees, investments in ICT and a state-of-the-art technical equipment usually increase establishment productivity (Black and Lynch, 2001), while establishments facing international competition and those with co-determination are more productive (Wolf and Zwick, 2002). Also productivity differences between four legal establishment forms (Harhoff, Stahl and Woywode, 1998) and the share of newly hired employees are taken into account. Finally, employee participation, teamwork, units with own costs and results accounting, stringent hiring rules and incentive payments are added as indicators for several dimensions of personnel management measures (Ichniowski et al., 1996). The descriptive statistics of the variables used can be found in table A1 in the appendix.

The estimation of equation (5) shows that training intensity in the first half of 1997 has a marginally significant positive impact on the fixed effects with a coefficient of 0.15 (see column 2 in table 2). The additional explanatory variables have the expected sign: the share of qualified employees and the dummies for exporting establishments, establishments investing in ICT and establishments having state-of-the-art equipment and works councils all have a positive impact on productivity, while individual establishments are significantly less productive than establishments with limited liability (the reference category). Employee participation, stringent hiring rules, units with own costs and results accounting, and incentive payments have a tendency to improve productivity, while the dummy for establishments with teamwork has a negative sign. Most personnel measures individually have an insignificant but jointly a significant impact on productivity[ix] because there is strong collinearity between these measures (Levine and Tyson, 1990; Ichniowski et al., 1996; Ichniowski, Shaw and Prennushi, 1997; Wolf and Zwick, 2002). The East Germany and the sector dummies are also jointly highly significant.

In contrast, for example, to Bartel (1994), the size of the estimated productivity impact of training is clearly reduced when we add further variables in matrix V_i, while the explanatory power of the regression increases. In a production function regression entailing besides capital, labor and training intensity only the East Germany dummy and the 15 sector dummies, the parameter of training intensity is highly significant and equals 0.94. A parsimonious estimation that only takes labor, capital, training and very few additional training parameters into account therefore suffers from omitted variable bias and tends to overestimate the productivity impact of continuing training in Germany.

In order to correct for selectivity bias in the regression described above, an instrumental variable regression is estimated according to equation (7), see column 4 in table 2. We use four instrumental variables and therefore have to test if the regression is overidentified. A Hansen overidentification test fails to reject that all four instruments can be included: the Hansen J statistic is 5.62, Prob > $?^2$ = 0.13. Changes in the set of identification variables, for example dropping both variables on the reactions of the personnel department on skill shortages, do not change the training coefficient substantially. The estimate for the instrumented training intensity is considerably higher and exhibits a higher significance level than that of the training intensity without endogeneity correction, and the coefficient is equal to 0.76. This means that those establishments that increased the share of trained employees by 1% in 1997 could increase average productivity in the period 1998-2001 by more than 0.7%. We learn from this exercise that establishments have a higher inclination to train in times of a productivity disadvantage. This result can be interpreted in different ways. Probably, establishments train in slack periods, i.e. when it is cheap to entrust employees with other tasks than production, or they train in order to catch up with the productivity level of their competitors (Bartel, 1994;

Black and Lynch, 2001; Nickel, Nicolitsas and Patterson, 2001; Zwick, 2005). Not taking into account that training intensity is a choice variable therefore underestimates 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.

The regression results are in line with those from the literature. Dearden, Reed and van Reenen (2000) find an impact of sector training intensity on sector productivity of around 0.8. Training in the establishments frequently is assigned to those employees who are best able to benefit from it. Therefore, the estimated productivity effect is a so-called "treatment on the treated" effect instead of an average productivity effect, and one might assume that the productivity effect of training would decrease if training intensity would be increased more than marginally. Nevertheless training seems a potent means to increase average productivity of the work force. Omitted variable bias would again change these results. When we re-calculate the second estimation step in table 2, taking account of selectivity and including besides the training intensity only the East Germany dummy and the sector controls, we would obtain an impact of training intensity on average establishment productivity of 5.01.

Several observers note that the productivity effects of training may not be universalistic but contingent on other establishment characteristics or the establishment´s environment (Levine and Tyson, 1990; Ichniowski et al., 1996; Ichniowski, Shaw and Prennushi, 1997). Bresnahan, Brynjolfsson and Hitt (2002) for example argue that training and investments in ICT are complements that reinforce the productivity effect of the single measure. Cappelli and Neumark (2000) stress that there might be synergies between high performance workplace measures such as team work, gainsharing, profit sharing, employee participation, and training that should be taken into account empirically. Zwick (2004c) for example shows that the productivity effects of training are stronger in German establishments with works councils. In order to test heterogeneities in the productivity effects of training, interaction terms between training and investments in ICT and the personnel management measures included in the production function are added. This is approach is frequently used in comparable settings (Huselid, 1995; Bresnahan, Brynjolfsson and Hitt, 2002). In accordance with most of the literature (Huselid, 1995; Delaney and Huselid, 1996, Huselid and Becker, 1996), no significant interaction term could be identified, however, neither if the interaction terms were added individually nor jointly. Reasons for the low complementarities found may be that the establishments already successfully exploit them and that there are strong collinearities between training and ICT investments or participative human resource measures (Huselid and Becker, 1996; Bresnahan, Brynjolfsson and Hitt, 2002).

Conclusions

This paper shows that increasing the training intensity has a positive and significant effect on establishment productivity in Germany. We know from other studies, however, that not all training forms increase productivity (Zwick, 2005). In addition, we can assume that the training effect is lower for those establishments that decided not to invest in training. Therefore no firm conclusions can be obtained if more establishments should offer continuing training or if the training establishments should increase their training intensity.

This paper takes account of selectivity in training by using expected skill shortages and personnel department activity as instruments that identify the training decision. In addition, unobserved heterogeneity is corrected by estimating a fixed effects panel estimation. If both sources of estimation bias are controlled simultaneously, it is found that an increase in training intensity in the first half of 1997 by one percent increases average establishment productivity in the period 1998-2001 by around 0.76 percent.

The estimations demonstrate that selectivity bias reduces the measured productivity impact. Therefore establishments strategically intensify training when they expect qualification gaps in the future and cover their qualification demand mainly by own training efforts instead of hiring qualified labor from the labor market. It can be concluded that one motivation of establishments to increase training intensity is an attempt to regain competitiveness and to close qualification gaps because training is a suitable means to reduce these gaps with respect to competitors. This paper also detects significant omitted variable bias. If a broad variety of establishment, employee and especially personnel management characteristics is not taken into account, the estimated productivity impact of training intensity is much too high.

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Table 1: Explaining training intensity 1997, equation (6)

Exogenous Variables	Coefficients	z-Value
High qualification need expected (instrument)	0.087**	4.26
Apprenticeship training high priority reaction on skill shortages (instrument)	0.029*	2.06
Training high priority reaction on skill shortages (instrument)	0.095**	6.22
Share new employees	0.045	1.49
Apprenticeship training	0.041**	3.02
Collective wage agreement	0.032*	2.40
Share of qualified employees	0.037	1.67
Exporter	0.004	0.24
State-of-the-art technical equipment	0.033**	2.81
Investor in IT	0.019	1.52
Co-determination	0.014	0.86
Individual firm	0.019	0.85
Partnership	- 0.052	- 1.74
Publicly listed company	0.332	1.55
Employee participation	0.035*	2.16
Teamwork	0.029	1.48
Units with own costs and results accounting	- 0.009	- 0.44
Stringent hiring rules	0.030	1.77
Incentive payments	0.040	1.87
Constant	- 0.008	- 0.28
15 sector dummies, 5 size dummies and 1 East Germany dummy	Yes	
Centered R^2	0.15	
Partial R^2 of excluded instruments	0.03	
Test of excluded instruments F(38, 2051) = 11.76	0.00	
Number of observations	2090	

Source: IAB Establishment Panel, Waves 1997 and 1998, own calculations.

Comment: The significance levels are marked by stars: ** significant at 1 percent and * at 5 percent, heteroscedasticity corrected standard errors.

Table 2: Explaining average fixed productivity effect 1998 – 2001

	panel OLS, equation (5)		panel OLS with instrumental variable estimation, equ. (7)	
Exogenous Variables	Coefficients	t-Values	Coefficients	t-Values
Training intensity	0.145	1.95	0.761*	2.13
Share of new employees	- 0.059	- 0.56	- 0.043	- 0.23
Apprenticeship training	0.097*	2.36	0.323**	7.71
Collective wage agreement	0.151**	3.45	0.227**	5.21
Share of qualified employees	0.638**	7.96	0.611**	7.51
Exporter	0.238**	4.05	0.333**	5.73
State-of-the-art technical equipment	0.169**	4.17	0.164**	3.87
Investor in IT	0.101*	2.50	0.091*	2.25
Co-determination	0.546**	9.63	0.790**	13.69
Individual establishment	- 0.396**	- 5.71	- 0.800**	- 15.57
Partnership	- 0.180	- 1.47	- 0.178**	- 2.60
Publicly listed company	0.956	1.62	0.251*	2.43
Employee participation	0.066	1.35	0.068	1.34
Teamwork	- 0.010	- 0.16	0.063	1.04
Units with own costs and results accounting	0.043	0.71	0.111	1.82
Stringent hiring rules	0.117*	2.22	0.184**	3.40
Incentive payments	0.075	1.19	0.116	1.76
Establishment size 20-199	0.849**	16.85	0.861**	17.40
Establishment size 200-499	1.380**	15.59	1.397**	16.20
Establishment size 499-1000	1.388**	10.17	1.440**	11.05
Establishment size 1000+	1.655**	13.43	1.723**	14.12
Constant	- 1.279**	- 12.13	- 0.778**	- 5.74
15 sector dummies and East Germany dummy	Yes		Yes	
Number of observations	2090		2079	
Adjusted R^2	0.6478		0.6350	

Source: IAB Establishment Panel, Waves 1997 - 2002, own calculations. All explanatory variables are in values of 1997.

Comment: The significance levels are marked by stars: ** significant at 1 percent and * at 5 percent. The standard errors are heteroscedasticity corrected.

Appendix

Table A1: Descriptive Statistics 1997

Variables	Average	Comments
Training intensity 1997	0.20	Number of trained employees in first half of 1997/number of employees on 1st June 1997
High qualification need expected	0.06	Over the next 2 years, a large demand for training and qualifications is expected, Yes/No
Apprenticeship training reaction to skill shortage	0.32	Apprenticeship training has highest priority to fill skills gap (in contrast to training and hiring skilled workers), Yes/No
Training reaction to skill shortages	0.30	Training own employees has highest priority to fill skills gap (in contrast to apprenticeship training and hiring skilled employees), Yes/No
Investor in IT	0.69	Investment in communication or electronic data procession, Yes/No
Co-determination	0.34	Establishment has a works council, from wave 1998, Yes/No
Employee participation	0.23	Establishment shifted responsibility and decision to lower ranks, Yes/No
Teamwork	0.16	Establishment has team work and independent groups, Yes/No
Units with own costs and results accounting	0.12	Establishment has units with own costs and results accounting, Yes/No

Table A1: continued

Stringent hiring rules	0.27	Establishment has stringent formal hiring rules, Yes/No
Incentive payments	0.13	Establishment has profit sharing or employee share ownership, Yes/no
Share of qualified employees	0.53	Share of employees in jobs that require at least a degree from apprenticeship training.
Share of new employees	0.08	Share of employees hired less than one year ago
Exporter	0.09	Exporter, from wave 1998, Yes/No
State-of-the-art technical equipment	0.73	Technical equipment is marked state-of-the-art in comparison to sector, Yes/No
Establishment size 1-19 (ref.)	0.40	Establishment has 1-19 employees
Establishment size 20-199	0.40	Establishment has 20-199 employees
Establishment size 200-499	0.10	Establishment has 200-499 employees
Establishment size 500-999	0.04	Establishment has 500-999 employees
Establishment size 1,000+	0.06	Establishment has more than 1,000 employees
Collective wage agreement	0.68	Establishment is subject to collective wage agreements, Yes/No
Apprenticeship training	0.61	Establishment offers apprenticeship training, Yes/No
Individual establishment	0.27	Individual establishment, Yes/No
Partnership	0.10	Partnership, Yes/No
Limited company (reference category)	0.49	Limited company, Yes/No
Publicly listed company	0.07	Publicly listed company, Yes/No

Source: IAB Establishment Panel, Waves 1997 and 1998, average sample values, own calculations.

Table A2: Descriptive Statistics 1998

Variables	Average	Comments
Value Added	14.48	Sales minus input costs and costs for third parties, deflated, ln, from wave 1999
Capital	13.99	Proxy: Perpetual inventory method, in DM, ln, deflated, from wave 1999
Labor	3.21	Number of employees at 1st June 1998, ln

Source: IAB Establishment Panel, Waves 1998 and 1999, representative values, own calculations.

Table A3: Descriptive Statistics 1999

Variables	Average	Comments
Value Added	14.52	Sales minus input costs and costs for third parties, in DM, ln, deflated, from wave 2000
Capital	14.02	Proxy: Perpetual inventory method, in DM, ln, deflated, from wave 2000
Labor	3.17	Number of employees at 1st June 1999, ln

Source: IAB Establishment Panel, Waves 1999 and 2000, own calculations.

Table A4: Descriptive Statistics 2000

Variables	Average	Comments
Value Added	14.69	Sales minus input costs and costs for third parties, in DM, ln, deflated, from wave 2001
Capital	14.07	Proxy: Perpetual inventory method, in DM, ln, deflated, from wave 2001
Labor	3.14	Number of employees at 1st June 2000, ln

Source: IAB Establishment Panel, Waves 2000 and 2001, own calculations.

Table A5: Descriptive Statistics 2001

Variables	Average	Comments
Value Added	14.78	Sales minus input costs and costs for third parties, in DM, ln, deflated, from wave 2002
Capital	14.25	Proxy: Perpetual inventory method, in DM, ln, deflated, from wave 2002
Labor	3.15	Number of employees at 1st June 2001, ln

Source: IAB Establishment Panel, Waves 2001 and 2002, own calculations.

Table A6: Fixed effects productivity estimation, value added 1998 – 2001, equation (4).

	Coefficients	z-values
Capital	0.23	1.79
$Capital^2$	- 0.02	- 1.53
Labor	0.20	1.05
$Labor^2$	0.06	1.78
Capital*Labor	0.01	0.50
Year Dummy 1999	0.02	1.09
Year Dummy 2000	0.08**	4.72
Year Dummy 2001	0.09**	5.42
Constant	11.62**	14.75
Number of observations	10,301	
F(8,4289)	22.50	Prob > F < 0.001
Adjusted R^2	0.81	

Source: IAB Establishment Panel, Waves 1998 - 2002, own calculations.

Comment: The significance levels are marked by stars: ** significant at 1 percent and * at 5 percent. The standard errors are heteroscedasticity corrected.

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[i] An alternative to the within estimator is the GMM estimator proposed by Arellano and Bover (1995). This estimator has several disadvantages in our case, however. First, it uses information only from establishments that answered in at least three periods in a row, and therefore many establishments drop out. Second, the capital and labor intensities obtained are not satisfactory. Third, the results are strongly dependent on the underlying specification, for example, which internal instruments are used if sector and time dummies and/or their interactions are included. Therefore, the results based on this estimator are not presented here.

[ii] The F-test of joint significance of the additional variables is F(3,4289) = 2.72, Prob > F < 0.05.

[iii] The exact question was: "Did your establishment sponsor continuing training in the first half of 1997? This means: Were employees on leave for internal and external training measures or were costs for

continuing training partly or fully covered by the establishment?”. In another question the number of employees participating in continuing training was asked for.

[iv] The average depreciation rate is assumed to equal 10%, while the average growth rate of investments is assumed to equal 5% (Hempell, 2004). Changes in these assumptions did not influence the results from the productivity estimations.

[v] External instruments are additional covariates while internal instruments are additional moments of the endogeneous variable such as lags or differences.

[vi] The F-test of joint significance of these coefficients is $F(3,4289) = 2.72$, $Prob > F < 0.05$.

[vii] One would expect from national income and product accounts that labour accounts for two-thirds of value added and capital for one third (Black and Lynch, 2001).

[viii] The first stage is estimated on a larger sample in order to obtain more precise estimates. The second stage contains fewer observations due to missing data on training intensity or other control variables (compare also Black and Lynch, 2001).

[ix] The F-test of joint significance of the personnel measures is $F(5,2054) = 2.52$, $Prob > F < 0.05$.