The Impact of Continuous Training on a Firm's Innovations

Abstract

Keeping up with rapid technological change necessitates constant innovation. Successful innovation depends on both incumbent workers' knowledge, based on experience, and knowledge about the latest technologies, along with the skills needed to implement them. Both of these knowledge-based elements of innovation can be attained through moderate labor force turnover in combination with continuous training. Based on German micro data, we find empirical evidence in support of training leading to innovation within a multivariate regression framework. However, when instrumenting training by the existence of a union's contract or a works council this impact disappears.

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1. Introduction

In the contemporary knowledge-based society, the production of new knowledge has usurped the place of traditional production, which is based on labor and capital. Romer (1986), in looking for an explanation for ongoing and endogenous growth, was the first to formalize the idea that an existing knowledge stock provides the basis for further knowledge production and thus innovation, or, in other words, today's researchers "stand on the shoulders" of predecessor researchers. Increasingly intense competition due to globalization, along with rapid technological change make constant innovation the only way to stay competitive. This holds at both the national level (Aghion *et al.* 2005) as well as at the firm level. Aghion *et al.* (2006) present a model where incumbent firms who fail to innovate on a regular basis are in danger of being evicted from the market by new entry. Accordingly, incumbents have to "use innovation as the main battle weapon with which they protect themselves from competitors and with which they seek to beat those competitors out." (Baumol 2002, p. 2). We extend this idea by arguing that if innovation is the weapon, education and, especially, training are the ammunition that render it useful and effective.

Our argument is grounded in Becker's (1964) fundamental theory on training and takes into consideration extensions of that theory by Acemoglu and Pischke (1999). All of these previous approaches have one thing in common: they assume an environment where price competition determines the incentive to invest in training. If the firm can appropriate parts of the future rent that results from a worker's increased productivity, it will invest in procuring that productivity. However, according to Schumpeter (1942), price competition is only one part of the story of rent distribution. Another and important part has to do with how these rents are created in the first place and to understand this, one must take into consideration the entire innovation "lifecycle"—from the birth of a new idea to its commercialization.

We argue that innovation is the only way to prevent entry and/or beat out the competitors (Aghion *et al.* 2006). Incumbents must innovate in order to stay at the leading edge of the technology frontier, which is where market leaders can expect monopoly (or oligopoly) rents as a way of reimbursing them for the R&D and training costs that made their advantage possible. However, fierce competition at the technology frontier means that small weaknesses and failures can be a matter of life and death, a situation that inhibits incumbents from undertaking risky and adventuresome innovation. Instead, they rely on *routinized* innovations, which do not come out of thin air. Rather, they encompass building on existing but still fairly recent knowledge and further improving and extending it (Baumol 2002a). Eventually, the routinization of innovation results in a firm-internal knowledge stock comprised of both knowledge gleaned from former experience (as embodied in the workers) *and* the latest technological knowledge and skills. However, such a valuable knowledge stock can only be achieved by means of moderate turnover in the labor force along with continuous training so that skills will be commensurate with the latest technology. Accordingly, we assume that firms operating successfully at the technology frontier and innovating constantly must rely on continuous training, that is, training is a necessary condition for successful innovation.

To test this hypothesis empirically, we employ German micro-level panel data provided by the Institute for Employment Research (*Institut für Arbeitsmarkt- und Berufsforschung*). In a multivariate regression framework, we find evidence consistent with the hypothesis that continuous training has a positive effect on a firm's ability to innovate. However, when instrumenting training by the existence of a union contract and a works council the positive effect of continuous training on a firm's innovations disappears.

The remainder of the paper is organized as follows. Section 2 focuses on our idea that escaping competition by way of innovation is a sound explanation for firm-sponsored training. Section 3 introduces our empirical method for testing the hypothesis that training influences innovation; Section 4 describes our data; and Section 5 presents the findings. We draw conclusions in Section 6, along with a few ideas for further research.

2. Training and Innovation

In his fundamental works on human capital, Becker (1964) emphasizes the importance of on-the-job training to a person's productivity over the lifetime. He argues that firms will only invest in specific training if they can appropriate the future rent of training. Motivated by first empirical findings by Steedmann (1993) and also Krueger (1993) and Autor (2001), Acemoglu and Pischke (1999) extend Becker's argumentation and argue that noncompetitive labor markets, in combination with a compressed wage structure, can also provide an incentive for firm-sponsored general training because firms can appropriate parts of the expected rent.[1] Both arguments appear to concentrate on the appropriability of future rents from the workers' increased productivity by employing a model of price competition in which firms compete over the future distribution of a given pie. However, according to Schumpeter (1942, p. 85), "it is not the kind of [price] competition which counts but the competition for the new commodity, the new technology, the new source of supply, the new type of organization (the largest-scale unit of control for instance)—competition which commands a decisive cost or quality advantage and which strikes not at the margins of the profits and the outputs of the existing firms, but at their foundations and at their very lives." Against this background, price competition is only one chapter in the story of the distribution of expected rents from training. How the rents are created in the first place is another important chapter, and to understand it, it is necessary to consider the innovation process, a process that involves

[1] Possible explanations for a compressed wage structure include transaction costs, such as search and matching fictions (Mortensen 1982; Diamond 1982); asymmetric information about the worker's true level of training (Katz and Zidermann 1990; Chang and Wang 1996); asymmetric information about an applicant's—particularly a young applicant without a comprehensive work record—motivation to apply for a new job (Is the applicant one of low ability who has been fired from a previous job or is he or she an underpaid high-ability worker?) (Acemoglu and Pischke 1998a); complementarities between the training of specific and general skills (Acemoglu and Pischke 1998b); and given labor market institutions such as minimum wages or labor unions (Acemoglu and Pischke 1998b, 1998b, 2003; Freeman and Medoff 1984).

the necessity of continuous investment in knowledge production and hence training for effective competition in the marketplace.

We extend this idea by arguing that training enables workers to experiment with the latest technologies in such a way that something new is created. Initially, this contributes to the firm's overall knowledge stock. A firm's knowledge stock, in turn, is the basis for the production of new knowledge and, eventually, the entire innovation process—from the birth of a new idea to its commercialization as a novel product or procedure. The general importance of constant innovation is described by Aghion *et al.* (2006) in a model where technologically advanced entry creates a competitive environment that forces incumbents to innovate constantly. In this environment, each potential entrant arrives with leading-edge technology. If the incumbent is less technologically advanced, the entrant will replace the incumbent. If the incumbent is also employing leading-edge technology, it can use its reputation advantage and block entry. In short, an incumbent who is approaching the development of leading-edge technology has a strong incentive to innovate and to keep pace with technological progress as doing so can prevent entry of competitors. However, an incumbent whose technology is out of date—regardless of whether it innovates—will find it difficult to keep pace with technological progress and, presumably, will not be able to prevent entry of leading-edge competitors. Consequently, an incumbent who lags considerably behind the times in terms of technology is discouraged from innovating and will be forced out of the market. The main implication of this model is that the threat of technologically advanced entry (escape-entry effect) or of competition in an oligopolistic market (escape-competition effect) encourages innovation by incumbents who are already in place at the technology frontier (Aghion *et al.* 2001, 2005). Innovation is the incumbent's weapon against entry and competition; training is the ammunition.

Taking a closer look at the innovation process itself, Baumol (2002) points out that in a competitive environment where firms do not dare to relax their innovative activities, innovation has to become a routinized process. In the process, "business firms systematically determine the amounts they will invest in the R&D process …, who and how many will be employed for the purpose and even select what it is that the company's laboratories should invent. In sum, competition makes it too risky for firms to depend primarily for their new products and processes on the unpredictable efforts of independent inventors. Instead they have changed much of the economy's R&D into an internal, bureaucratically controlled process" (2002, p.2). In this situation, incumbent firms are likely to rely on their existing knowledge stock as the basis for further improvements and extensions. However, the firm's knowledge stock is comprised of more than just codified knowledge, i.e., patents and how-to manuals. An equally, if not more so, important component of the knowledge stock is tacit knowledge, i.e., know-how and know-who (Lundvall and Johnson 1994). Know-how, which is gained from former experience, and know-who, which arises from social contacts, are "sticky" types of knowledge, meaning that they are "stuck" to the person in possession and cannot be created artificially or bought by employing new workers. This type of knowledge is the product of an evolutionary process in which colleagues have worked together in teams and know about the strengths and weaknesses of each other, leading to complementarities that raise productivity per se. Furthermore, previous experience with development processes and related problems can be relied on to avoid difficulties in further exploitation of the existing knowledge stock (see Nelson and Winter 1982).

Thus, high turnover in the workforce is likely to destroy the social ties that can increase productivity. However, according to Granovetter (1973), closed networks have their dangers, too, including the risk of inflexibility and decrepit structures that can result from a lack of "new blood." In this context, training, along with moderate labor force turnover, provides a simple way to collect new knowledge and thus prevent inflexibility and blindness that are inherent in decrepit structures, both of which are major obstacles to innovation. We thus argue that a sustainable company's decision to invest in training does not depend on whether it can recoup training costs by paying noncompetitive wages and/or instituting a compressed wage structure. Rather, firms have an incentive to pay at least competitive wages to preserve the tacit part of their knowledge stock and, at the same time, they have an incentive to invest in training as a way to extend the codified part of the knowledge stock and keep up with the latest technological changes and requirements. Given an incumbent firm's reliance on experience, continuous training of the routinized workforce is a necessary investment to steadily refresh the firm's knowledge stock that, in turn will provide the basis for further innovation.

In the following sections, we empirically test the hypothesis that continuous training has a significant impact on a firm's innovative ability and thus its competitiveness.

3. Method

To test the hypothesis of whether continuous training supports firm innovations, we define a binary variable, continuous training, that takes the value 1 if a firm regularly trains its employees and 0 otherwise; the variable for innovation is also binary and takes the value 1 if a firm was innovative in a specific year and 0 otherwise.

To reduce potential problems of endogeneity in our model, we use a twofold strategy: First, we lag the training variable and do not consider training at a single year but instead we focus on the continuity in training, i.e. on those establishments that trained their employees continuously during the whole period of observation. This strategy helps us to reduce the problem of reverse causality, i.e. a firm trained its employees because of an innovation requiring new skills of the firm's workforce. However, this strategy will not help us to overcome the problem of reverse causality in the case of a firm that continuously innovates.

To control for the latter case we add the lagged innovation variable in our estimation model. The effects of continuous training on the firm's propensity to innovate (INNO) are estimated in a probit model while controlling for specific firm-level and industry-level characteristics with e_1 as an error term.

$$\text{INNO}: \text{I} \; \left(1 \middle| \text{continuous training, firm level and industry level characteristics}, e_1\right) \tag{1}$$

Angrist (2001) suggests to use simple linear identification strategies when estimating causal effects even though the dependent variable is a 0-1-dummy variable. Therefore, we additionally use a linear probability regression to estimate the effects of continuous training on a firm's propensity to innovate while controlling for firm-level and industry-level characteristics.

Although we control for a lot of firm-level and industry-level characteristics in our multivariate regression framework, we still worry about an omitted variable bias. An instrumental variable approach where continuous training is instrumented by variables that can explain training but do not correlate with the error term of the innovation equation could help us to overcome this problem. In the instrumental variable approach, we focus on the variation in continuous training activities induced by the instruments and analyze whether this variation can explain a firm's propensity to innovate.

When looking at the determinants of training, we find two variables that seem to be interesting instruments, namely the existence of a union contract and the existence of a works council. It has been found in empirical studies that these institutions do not have a direct impact on innovation (cf. Schnabel and Wagner 1994; Addison et al. 2004) but heavily determine a firm's decision to train (Bellmann and Leber 2005; Neubäumer and Kohaut

2008).[2] Therefore, union contracts and work councils might influence a firm's innovative ability indirectly by encouraging training activities. When reading through various German union contracts, one notices that the vast majority of these contracts include sections on qualification and training of employees (Bispinck 2000). Unfortunately, these regulations and recommendations are so diverse and different from each other that it is not possible to make them comparable by categorization. Concerning the impact of work councils on training, §§ 96-98 of the German Works Council Constitution Act (*Betriebsverfassungsgesetz*) give information that work councils are legally entitled to foster and take part in the decision making process on training activities of the employees. Thus, the existence of union contracts and works councils might have a positive impact on a firm's innovative activities simply by encouraging training of the employees. To analyze this line of causality, we use an instrumental variable approach, where continuous training is instrumented by the existence of a union contract and a works council. Doing this, we focus on the variation in continuous training activities induced by the existence of these institutions and analyze whether this variation can explain a firm's propensity to innovate.

Both the continuous training and the innovation variable are binary variables. Therefore, we would use nonlinear probit models to analyze the determinants of a firm's propensity to innovate and to train continuously. Thus, continuous training is the independent variable of the innovation probit model and the dependent variable of the second probit model, i.e. continuous training is endogenized in this system of equations. However, nonlinear models cannot be solved in a two-stage instrumental variable framework. A feasible way to handle this problem is a recursive bivariate probit model where the error terms of the two probit

[2] Addison (2005) gives an overview over the empirical literature on the impact of works councils on German firm performance and shows that most of the studies focus on productivity effects, either in terms of sales or value added. Some studies find that works councils influence training/innovative work practices and thereby have an indirect impact on productivity. However, little is said about the direct or indirect impact of works councils on a firm's product innovations.

models are allowed to be correlated (Evans and Schwab 1995). In this seemingly unrelated bivariate probit model the probit equations on training and innovation are estimated simultaneously.

$$\text{INNO: I}\ \left(1 \middle| \text{continuous training, firm level and industry level characteristics, } e_1\right) \tag{2}$$

$$\text{CONTRAIN: I}\ \left(1 \middle| \text{union contract, works council, firm level and industry level characteristics, } e_2\right) \tag{3}$$

$$E[e_i] = E[e_2] = 0;\ \text{var}[e_1];\ \ \text{var}[e2];\ \text{cov}[e_1, e_2] = \rho \tag{4}$$

Following Angrist (2001), we alternatively estimate an ordinary instrumental variable two-stage least squares regression (i.e. a linear probability model), where innovation is used as a dependent variable and the regressor, continuous training, is instrumented by the existence of a union contract and a works council.

4. Data

Information on innovative activities, continuous training and additional firm-level characteristics is generated from the IAB establishment panel (Betriebspanel), waves 1997–2001. Data access was provided via on-site use at the Research Data Centre (FDZ) of the German Federal Employment Agency (BA) at the Institute for Employment Research (IAB) and/or remote data access. For a detailed description of this data source see Bellmann (2002). Access to the data was granted during a research period at the Research Data Centre of the Federal Employment Agency at the Institute for Employment Research (FDZ) and via controlled data teleprocessing at the FDZ. As the name establishment panel implies, the establishment, and not the company, constitutes the unit of measurement. Thus, we have two categories of entities: firm headquarters and subsidiaries. Both are treated equally in the following analysis. Businesses contained in the German Social Insurance Statistics form the population of the IAB establishment panel. The businesses are selected according to the principle of optimum stratification of the random sample. Because the stratification cells are defined by business size categories and industries, these dimensions must later be included in the econometric estimations to ensure representative results. The establishment panel data comprise the results of annual surveys of businesses that have been carried out in West Germany since 1993 and in East Germany since 1996. The annual surveys cover questions on a series of firm characteristics. Additional complexes of questions dealing with special topics, such as working time flexibility, elder employees, or innovative activities, are included in selected annual catalogues.

To analyze the impact of continuous training on a firm's ability to innovate, we use data for the period 1997–2001. Only those businesses that answered the questionnaire in every year of this period are included in our dataset. Furthermore, the whole public sector is excluded, resulting in a balanced panel of 3,198 private-sector businesses for the period 1997–2001. This represents a uniquely rich source of data for our analysis.

The panel data are transformed into cross-section data by defining variables that span more than one year. Information on innovative activities is available for the years 1998 and 2001. In these years, the firms were asked whether they introduced a completely new product/service during the past two years, whether they newly adopted a product/service, or whether they enhanced an existing product/service. Strictly speaking, only the answer to the first question (introduction of a completely new product/service) can be called a true innovation. However, for our analysis, innovation is more broadly defined and the variable *innovation* is given a value of 1 if a firm carried out any of the above-mentioned innovative activities; 0 otherwise. Since firms are likely to rely on their existing knowledge stock as a basis for further improvements and extensions, the information on whether a firm was innovative in 1998 is expected to be an important determinant of innovative ability in 2001.

Information on training is drawn from the 1997, 1999, and 2000 surveys. The interviewed firms were asked whether or not training for their employees was encouraged either by (partly) financing the training or by releasing the employees from work. The question referred to the first half of every year. If a firm promoted training, *tr*, in all the years *t*, the variable *CONTRAIN* (i.e., continuous training) takes the value 1, otherwise it is 0.

$$CONTRAIN = \begin{cases} 1 & \text{if } tr_t = 1 \text{ for all } t \text{, with } t = \{1997, 1999, 2001\} \\ 0 & \text{otherwise} \end{cases}$$

Information on various firm-level characteristics is available from the establishment panel and is introduced in our model in the form of control variables. The number of employees is used to capture firm-size effects. More specifically, 10 firm-size classes were generated according to the average number of employees in the period 1997–2000. Then, the logarithm of this categorical variable was taken to create the firm-size variable used in the model. Thus, the subproportional path of the logarithmic function can be maintained for more establishments, with the last firm-size class including all establishments with 2,000 or more employees. Further characteristics of a firm's employment structure include the average fraction of skilled employees, the average fraction of unskilled employees, and the average fraction of part-time employees, again for the period 1997–2000. Furthermore, the variable *labor turnover* is generated to measure employment fluctuations at the firm-level. Following Neubaeumer and Kohaut (2008), we define labor turnover, *lt*, as:

$$lt = \frac{\sum_{t=1997}^{2000} 0.5 * (ne_t + de_t)}{\sum_{t=1997}^{2000} ae_t},$$

where ne_t is the number of new employees in year t, de_t is the number of dismissed employees in t, and ae_t is the number of all employees in year t. Moreover, several dummy variables are introduced to inform about other firm characteristics. Among them are variables that take on the value 1 if the firm invested in information and communication technologies or in production technologies in at least one year between 1997 and 2000; otherwise 0. Another binary variable encodes information on whether a firm undertook any organizational changes in 1998; the question on reorganization activities was not included in the 1997 catalogue. Firms with their own research and development departments might be more innovative and offer more training than other firms, all other factors being equal, and we thus introduce a research and development dummy that takes the value 1 if the establishment itself or an affiliate had a research and development department in 1998. The technical condition of firm's machines is also captured by a dummy variable, with a value of 1 if the machines were considered cutting-edge or modern, and 0 if they were considered middle-aged or old, in 1997. The variable *union contract* was originally meant to take the value 1 if a firm had a labor agreements with unions from 1997 until 2000, with firms not continuously tied to union contracts as a reference group. However, Neubaeumer and Kohaut (2008) note that in this establishment panel, a skip in the dummy variable *union contract* over the years almost exclusively appears temporary, at least for the period from 2001–2005. Therefore, they suggest transforming this variable when using it as a variable that spans several years. Consequently, our union contract variable takes on the value 1 if the establishment was tied to a union contract for at least three years between 1997 and 2000. Information on the existence of works councils is not available for all establishments during the whole period of observation; however, these data are available for the years 1998 and 2000. We took data from these two years to create a variable that is given the value 1 if a works council existed in both years and 0 otherwise. A final firm-level dummy variable is used to capture the age of the firm and is 0 if the firm was established before 1990 and 1 if it was established in 1990 or later.

To capture time-invariant industry-level effects, industry dummy variables distinguishing between 23 private-sector industries are introduced. Furthermore, a West/East Germany dummy, as well as the logarithm of the ratio employees versus whole population of an administrative district (German *Kreis*), are used to represent specific regional effects, i.e., agglomeration economies. The regional employment data are derived from the German Social Insurance Statistics and were merged with the establishment panel. A detailed description of the structure of establishments contained in our generated dataset, e.g., distribution of the firms over the private-sector industries or over the firm-size classes, can be found in the Appendix.

Table 1 provides statistics on continuous training and innovative activities by industries. The propensity to continuously train employees varies across the industries. It appears to be common practice for *energy/mining/water supply*, *chemical industry/petroleum processing*, *shipbuilding/aircraft construction*, and *credit institutions* to train their employees; however, only a few firms in *agriculture/forestry*, *wood working*, *building industry*, or *restaurants/accommodation services* engage in continuous training. Industry-specific differences are also apparent when it comes to innovative activities. *Chemical industry/petroleum processing*, *plastics/rubber industry*, *electrical engineering/data processing machines*, and *shipbuilding/aircraft construction* are the most innovative. *Agriculture/forestry*, the *building industry*, *real estate services*, and *restaurants/accommodation services* seem to be rather conservative in this regard.

Table 1: Continuous training and innovative activities across industries

	Continuous training in 1997, 1999 and 2000			Innovation 1999-2001		
	No	Yes	Total	No	Yes	Total
Agriculture and forestry	131	25	156	133	23	156
	83.97	*16.03*	*100.00*	*85.26*	*14.74*	*100.00*
Energy, mining, water supply	12	71	83	55	23	78
	14.46	*85.54*	*100.00*	*70.51*	*29.49*	*100.00*
Chemical industry, petroleum processing	7	43	50	12	39	51
	14.00	*86.00*	*100.00*	*23.53*	*76.47*	*100.00*
Plastics, rubber industry	16	12	28	/	26	/
	57.14	*42.86*	*100.00*	/	/	*100.00*
Earths, stones and fine ceramics industry	37	26	63	25	38	63
	58.73	*41.27*	*100.00*	*39.68*	*60.32*	*100.00*
Iron, steel and metal industry	37	58	95	37	59	96
	38.95	*61.05*	*100.00*	*38.54*	*61.46*	*100.00*
(Light) Metal construction	71	110	181	57	125	182
	39.23	*60.77*	*100.00*	*31.32*	*68.68*	*100.00*
Electrical engineering, data processing machines	40	77	117	26	90	116
	34.19	*65.81*	*100.00*	*22.41*	*77.59*	*100.00*
Road vehicle manufacturing, garages	28	62	90	45	44	89
	31.11	*68.89*	*100.00*	*50.56*	*49.44*	*100.00*
Shipbuilding, aircraft construction	/	11	/	0	11	11
	/	/	*100.00*	*0.00*	*100.00*	*100.00*
Fine mechanics, toys industry	32	32	64	18	46	64
	50.00	*50.00*	*100.00*	*28.13*	*71.88*	*100.00*
Wood working	59	10	69	42	27	69
	85.51	*14.49*	*100.00*	*60.87*	*39.13*	*100.00*
Paper and printing industry	27	20	47	29	18	47
	57.45	*42.55*	*100.00*	*61.70*	*38.30*	*100.00*
Textile industry	29	19	48	20	26	46
	60.42	*39.58*	*100.00*	*43.48*	*56.52*	*100.00*
Food, beverages and tobacco industry	73	49	122	58	62	120
	59.84	*40.16*	*100.00*	*48.33*	*51.67*	*100.00*
Building industry	318	109	427	329	95	424
	74.47	*25.53*	*100.00*	*77.59*	*22.41*	*100.00*
Trade	359	193	552	362	181	543
	65.04	*34.96*	*100.00*	*66.67*	*33.33*	*100.00*
Communications and information transmission	87	85	172	115	57	172
	50.58	*49.42*	*100.00*	*66.86*	*33.14*	*100.00*
Credit institutions	6	92	98	28	70	98
	6.12	*93.88*	*100.00*	*28.57*	*71.43*	*100.00*
Insurance industry	18	30	48	17	31	48
	37.50	*62.50*	*100.00*	*35.42*	*64.58*	*100.00*
Real estate services	32	30	62	46	16	62
	51.61	*48.39*	*100.00*	*74.19*	*25.81*	*100.00*
Restaurants, accomodation services	144	22	166	127	40	167
	86.75	*13.25*	*100.00*	*76.05*	*23.95*	*100.00*
Other Services	267	174	441	288	148	436
	60.54	*39.46*	*100.00*	*66.06*	*33.94*	*100.00*

Note: / signifies anonymized data

Concerning the impact of continuous training on a firm's innovative activities, a simple computation of the relative frequency suggests that continuous training of employees positively influences innovation activity.

Table 2: Cross tables on continuous training and innovations across size classes

Avg no. of employees	Continuous training	Innovation 1999-2001 No	Innovation 1999-2001 Yes	Innovation 1999-2001 Total
Total	No	1,315	500	1,815
		72.45	*27.55*	*100.00*
	Yes	552	792	1,344
		41.07	*58.93*	*100.00*
	Total	1,867	1,292	3,159
		59.10	*40.90*	*100.00*
1-4	No	80.31	19.69	100.00
	Yes	75.00	25.00	100.00
	Total	79.87	20.13	100.00
5-9	No	75.95	24.05	100.00
	Yes	56.38	43.62	100.00
	Total	71.98	28.02	100.00
10-24	No	71.79	28.21	100.00
	Yes	54.81	45.19	100.00
	Total	67.14	32.86	100.00
25-49	No	60.18	39.82	100.00
	Yes	53.19	46.81	100.00
	Total	57.46	42.54	100.00
50-99	No	61.49	38.51	100.00
	Yes	46.06	53.94	100.00
	Total	53.35	46.65	100.00
100-249	No	60.00	40.00	100.00
	Yes	42.37	57.63	100.00
	Total	47.43	52.57	100.00
250-499	No	69.70	30.30	100.00
	Yes	34.59	65.41	100.00
	Total	39.91	60.09	100.00
500-999	No	81.82	18.18	100.00
	Yes	31.20	68.80	100.00
	Total	35.29	64.71	100.00
1000-1999	No	75.00	25.00	100.00
	Yes	17.14	82.86	100.00
	Total	18.75	81.25	100.00
2000 and more	No	0.00	100.00	100.00
	Yes	11.27	88.73	100.00
	Total	11.11	88.89	100.00

Table 2 shows that those establishments that continuously trained their employees during the period 1997–2000 exhibited more innovative activities from 1999 to 2001. While only 28 percent of the establishments that did not continuously train reported innovative activities, this number more than doubles and rises to 59 percent for the establishments that continuously train their employees. Even across the single firm-size classes, this correlation is confirmed, with the exception of the very big establishments. In this category, one firm did not train its employees but was an innovator, resulting in a 100 percent innovator rate among the firms that do not train continuously in this group.

5. Results

We estimate a nonlinear probit regression and a linear probability regression with innovation as a dependent variable that signifies whether the firm undertook any kind of innovative activity between 1999 and 2001. As the main regressor of interest we use continuous training in 1997, 1999, and 2000. All models in this section are estimated using robust standard errors.

Column 1 of Table 3 presents the results of the probit model. We find a positive influence of continuous training on a firm's innovative ability. This effect shows highly significant. Furthermore, it can be seen that the existence of a union contract has no significant effect on innovation. This is exactly what we expected based on the empirical innovation literature (cf. Schnabel and Wagner 1994). Similarly, we find no significant direct impact of a works council on a firm's innovations. Interestingly, we see that the effect of labor turnover is positive, yet insignificant. The R^2s and the Hosmer-Lemeshow test statistics confirm a sound fit of the model. Hosmer-Lemeshow test statistics are used instead of ordinary Pearson chi^2 statistics since the number of covariate patterns does not differ much from the number of observations and thus an ordinary Pearson chi^2 test is less appropriate (Hosmer and Lemeshow 2000, pp. 140–145). Similar results are obtained with a linear probability regression (cf. column 2 of Table 3).

Table 3: Determinants of innovations: simple probit and OLS regressions

Independent Variable	Probit regression INNOVATION 1999-2001	Linear Regression INNOVATION 1999-2001
Constant	-2.007075 ***	-.1083071 *
	(.2360058)	(.0580497)
Continuous training 1997,1999,2000	.2451723 ***	.0781075 ***
	(.0694635)	(.0212789)
Log average number of employees 1997-2000	.1609916 **	.048103 **
	(.0696009)	(.0192658)
Average fraction of skilled employees 1997-2000	-.3059251	-.0699467
	(.201826)	(.0527939)
Average fraction of unskilled employees 1997-2000	-.1657358	-.041018
	(.2209845)	(.0583897)
Average fraction of part-time employees 1997-2000	-.5040503 ***	-.1411576 ***
	(.1729355)	(.0450414)
Labour turnover 1997-2000	.2879323	.0653807
	(.4228749)	(.1141243)
Investment in ICT 1997-2000	.3401941 ***	.0881465 ***
	(.0796458)	(.020589)
Investment in production technology 1997-2000	.2340427 ***	.0593351 ***
	(.0789489)	(.0201579)
Organisational changes in 1998	.3309213 ***	.093636 ***
	(.0655807)	(.0188595)
R&D department in 1998	.6885898 ***	.2172463 ***
	(.0850393)	(.0254287)
Technical condition of the machines in 1997	.0447866	.0124921
	(.0609125)	(.016624)
Union contract 1997-2000	-.0030044	-.0056543
	(.066646)	(.0188881)
Works council 1998-2000	-.1241666	-.0336488
	(.0843637)	(.0249636)
Some innovation in 1998	.6937816 ***	.2324211 ***
	(.0594559)	(.0200133)
Founding year	.1414595 **	.0433346 **
	(.0647865)	(.0181883)
Log Average fraction of employees on population 1997-2001	-.0674979	-.0217236
	(.0840576)	(.0247131)
West Germany	.1227076 *	.0375005
	(.0629898)	(.017869)
Industry dummies	Yes	Yes
	Number of observations 2,911	*Number of observations* 2.921
	Wald chi2 838.21	*F(39,2881)* 65.15
	Prob > chi2 0.0000	*Prob > F* 0.0000
	McFadden R2 0.2769	*R-squared* 0.3353
	Count R2 0.771	*Root MSE* .40353
	Adjusted Count R2 0.435	
	Hosmer Lemeshow chi2 2.88	
	Prob>chi2 0.942	

In Table 4, we focus on the determinants of continuous training. As expected, both the existence of a union contract and a works council exhibit a highly significant impact on a firm's propensity to train its employees continuously. This is true for the probit model (cf. column 1 of Table 4) as well as for the linear regression model (cf. column 2 of Table 4). The effect of a union contract and a works council on a firm's propensity to train continuously both prove to be significantly positive. The coefficients of the remaining control variables have the anticipated signs. Altogether, the models yield results in line with training estimations for single years (Bellmann and Leber 2005; Neubaeumer and Kohaut 2008).

Table 4: Determinants of continuous training: simple probit and OLS regressions

Independent Variable	Probit regression CONTINUOUS TRAINING	Linear regression CONTINUOUS TRAINING
Constant	-2.995997 *** (.2664676)	-.2076526 *** (.0490889)
Log average number of employees 1997-2000	.7487761 *** (.0815638)	.1856118 *** (.0188778)
Average fraction of skilled employees 1997-2000	.4932552 ** (.2326219)	.0681674 (.0429868)
Average fraction of unskilled employees 1997-2000	-.4564573 ** (.2604858)	-.1468892 *** (.0493266)
Average fraction of part-time employees 1997-2000	-.1408319 (.1790115)	-.0323097 (.0432324)
Labour turnover 1997-2000	-1.04204 ** (.4523206)	-.2747758 *** (.1003243)
Investment in ICT 1997-2000	.242201 *** (.0849152)	.0470883 *** (.0181814)
Investment in production technology 1997-2000	.2299202 *** (.08619)	.0545757 *** (.019094)
Organisational changes in 1998	.2184312 *** (.0692031)	.0549766 *** (.0175922)
R&D department in 1998	.3087096 *** (.0890658)	.0870828 *** (.0237205)
Technical condition of the machines in 1997	.2566838 *** (.0655106)	.0540344 *** (.0154347)
Union contract 1997-2000	.2219137 *** (.070549)	.054426 *** (.0190611)
Works council 1998-2000	.5587528 *** (.0842266)	.2275608 *** (.0258587)
Some innovation in 1998	.109266 * (.0657774)	.0286444 * (.0171781)
Founding year	-.0001418 (.0713776)	-.0014307 (.0170194)
Log Average fraction of employees on population 1997-2001	-.0305769 (.089324)	-.0050054 (.0220528)
West Germany	.0633637 (.069273)	.0133407 (.0164983)
Industry dummies	Yes	Yes
	Number of observations 2,946 *Wald chi2* 1083.56 *Prob > chi2* 0.0000 *McFadden R2* 0.3873 *Count R2* 0.803 *Adjusted Count R2* 0.534 *Hosmer Lemeshow chi2* 9.40 *Prob>chi2* 0.309	*Number of observations* 2.946 *F(39,2881)* 139.09 *Prob > F* 0.0000 *R-squared* 0.4334 *Root MSE* .37441

We finally apply instrumental variable methods, in which continuous training is instrumented by the existence of a union contract and the existence of a works council. The results of the seemingly unrelated bivariate probit and the instrumental variable two stage least squares regressions are given in Table 5.

Table 5: Determinants of innovations: IV regressions

Independent Variable	Seemingly unrelated bivariate probit estimation CONTINUOUS TRAINING	 INNOVATION 1999-2001	Instrumental variable regression INNOVATION 1999-2001
Constant	-2.943752 ***	-2.160794 ***	-.1384451 **
	(.2881532)	(.2512263)	(.0625042)
Continuous training 1997,1999,2000		-.6696602	-.0649435
		(1.284358)	(.0962908)
Log average number of employees 1997-2000	.745593 ***	.3412823	.0748943 **
	(.0840345)	(.2682285)	(.0312504)
Average fraction of skilled employees 1997-2000	.5045903 **	-.1902845	-.0592514
	(.2362983)	(.3122628)	(.0536634)
Average fraction of unskilled employees 1997-2000	-.4251538	-.2954689	-.0613519
	(.2643928)	(.2733512)	(.0603575)
Average fraction of part-time employees 1997-2000	-.1430111	-.5014293 ***	-.1457636 ***
	(.1767912)	(.1774775)	(.0454311)
Labour turnover 1997-2000	-.9732814 **	-.012486	.0255136
	(.4757306)	(.6237438)	(.1180879)
Investment in ICT 1997-2000	.2396861 ***	.3678988 ***	.0948521 ***
	(.0841535)	(.0777456)	(.0213143)
Investment in production technology 1997-2000	.2176261 **	.2749621 ***	.0669665 ***
	(.0859474)	(.0823245)	(.0209121)
Organisational changes in 1998	.2353901 ***	.3659975 ***	.1019366 ***
	(.0695598)	(.0647661)	(.0199773)
R&D department in 1998	.2947368 ***	.7174994 ***	.229625 ***
	(.0906598)	(.0874922)	(.0277019)
Technical condition of the machines in 1997	.2618671 ***	.1006507	.0202351
	(.065783)	(.1009749)	(.0172493)
Union contract 1997-2000	.1996612 **	.0570874	
	(.0789156)	(.1162302)	
Works council 1998-2000	.5654541 ***	.0840514	
	(.084387)	(.317519)	
Some innovation in 1998	.0925953	.6672616 ***	.2360781 ***
	(.0662413)	(.1324651)	(.0203812)
Founding year	-.0008548	.1327518 *	.0434389 **
	(.0724203)	(.0696664)	(.0181944)
Log Average fraction of employees on population 1997-2001	-.0027894	-.0656253	-.0222589
	(.0943457)	(.0812113)	(.0247733)
West Germany	.0766747	.1314749 **	.0401491
	(.0693011)	(.0606143)	(.0180323)
Industry dummies	Yes	Yes	Yes
/athrho	*.5991316*		
	(1.057083)		
rho	*.5364313*		
	(.7528984)		
	Number of observations	*2,921*	*Number of observations 2.921*
	Wald chi2(77)	*3,039.72*	*F(39,2881) 66.39*
	Prob > chi2	*0.0000*	*Prob > F 0.0000*
	Wald test of rho = 0		*R-squared 0.3235*
	chi2(1)	*.321237*	*Root MSE .40694*
	Prob > chi2	*0.5709*	*Hansen J statistic*
	Likelihood Ratio test of rho = 0		*chi2(1) 0.011*
	chi2(1)	*.918502*	*Prob > chi2 0.9156*
	Prob > chi2	*0.3379*	

As can be seen from Table 5, the coefficients for continuous training become negative in the innovation equations, although the *p* value shows that these effects are not significant. In both, the seemingly unrelated bivariate probit model and in the linear instrumental variable model, continuous training loses its influence on a firm's innovative activities when only using the variation in continuous training induced by unions and works councils. At the same time, the test of the joint influence of unions and works councils on continuous training at the first stage of the two stage least squares IV regression delivers an *F* value of 48.58. This proves that the chosen variables are strong instruments for training. The Hansen overidentification test of the instruments confirms this finding. For the seemingly unrelated probit model, a Wald test as well as a Likelihood Ratio test show that the null hypothesis $\rho = 0$ cannot be rejected (cf. Table 5). Yet, the result for continuous training is significantly different from zero in the univariate innovation probit model, whereas the bivariate probit estimation reports insignificant estimates for both the continuous training dummy and the correlation coefficient. This again hints at continuous training having no effect on innovation (Monfardini and Radice 2008).

Robustness Checks

To check the robustness of the results, some variations of the models are estimated. Since the main variable of interest, innovation, is a binary variable and the results of the linear probability models qualitatively show the same results, we focus on variations of the presented probit models.

First, the training period is shortened so that the regressor, *continuous training*, refers to training in 1997 and 1999 with all other variables being equal. Thus, a better lag between training and innovation is created to counter the argument of reversed causality of training and innovation by yet another means. The resulting probit model does not differ substantially from the one reported above: Continuous training has a significantly positive effect on a firm's innovations. To further widen the lag between training and innovation is not recommended, since that would imply that training leads to innovative activity only after a specifically defined period of time.

Second, the probit and biprobit models are estimated with a slight variation of the instrumental variable *union contract*. The variable is coded 1 only if the interviewed firm actually confirmed for every year between 1997 and 2000 that it was tied to a union contract. Again, the results do not differ considerably from the original models.

Furthermore, we estimated separate regressions for specific firm size classes. The regressions for those establishments with a) less than 25 employees, b) 25 and more employees, c) less than 50 employees, and d) 50 and more employees show similar characteristics to the regressions presented above. Our results remain robust. However, if we only consider establishments with 100 and more employees, our instrument becomes weak since there is too little variation in the existence of union contracts among larger firms.

In another specification of our model, we use data from the German Social Insurance Statistics to generate the Herfindahl index of concentration as computed by Schmalensee (1977), which considers the size distribution of sellers in a market and thus represents an alternative means of accounting for industry-level characteristics. This index is insignificant in the innovation equation when used together with the industry dummies. Without industry dummies, the Herfindahl index becomes significantly positive, which hints at more innovative activity in industries with less competitive pressure. A certain degree of concentration seems necessary to induce innovative activities. This finding is in line with Aghion *et al.* (2006), who argue that the opportunity for temporary rents in an imperfect goods market and, hence, competition, stimulates innovative activity. In this context, a high level of concentration indicates that incumbents are constantly innovating and thus manage to prevent entry. However, nothing can be said about potential competition caused by potential entries. Apart from that, we obviously face endogeneity problems because innovation alters the market position of some firms. Thus, coefficients should be interpreted as no more than correlations. The Herfindahl index also has a positive impact in the training equation, which is only significant at a 10 percent level of significance when used together with industry dummies. These results confirm Acemoglu and Pischke (1999), in that some market power seems to be necessary to encourage firm-sponsored training. However, this finding is in disagreement with that of Autor (2001), who finds that the Herfindahl index and training are negatively correlated in U.S. temporary employment firms and therefore suggests that less competition reduces training.

However, also in this specification of the model, our findings concerning the impact of continuous training on innovation are left unchanged, though the results are not included in the reported tables.

To apply yet another variable representing industry-level characteristics, we use the average entry rate per industry as a measure of competitive pressure. The entry rate is generated from data of the German Social Insurance Statistics and shows a significantly negative impact on innovation, which again is consistent with Aghion *et al.* (2006). New entry means that incumbents have not successfully defended their market position. It reduces the expected payoff from innovating and thus discourages innovation. However, these results should be interpreted tentatively due to potential endogeneity problems. The coefficients should at most be interpreted as correlations. Again, our findings as to the impact of continuous training on a firm's innovative ability are confirmed.

We also estimated the models for manufacturing industries only. Once more, similar results were found. However, it might be a problem that, in this case, the existence of a union contract is not an appropriate instrumental variable as it no longer has a significant effect in the training equation.

Finally, we examine whether continuous training favors radical innovations, which, in our context, means the introduction of completely new products or services. A binary-coded variable is generated that takes the value 1 only if the firm reported having undertaken such a "real" innovation in the period 1997–2001. The reference group is comprised of firms that introduced minor innovations during this same period, which, in this context, means imitation or enhancement of an existing product/service.

Table 6: Determinants of radical innovations: simple probit and OLS regressions

Independent Variable	Probit regression RADICAL INNOVATION vs. PRODUCT ENHANCEMENT/IMITATION 1999-2001	Linear regression RADICAL INNOVATION vs. PRODUCT ENHANCEMENT/IMITATION 1999-2001
Constant	-7.044758 *** (.6422553)	-.0705656 (.0904965)
Continuous training 1997,1999,2000	-.031542 (.1173465)	-.0063295 (.0290124)
Log average number of employees 1997-2000	.098223 (.1434431)	.0226688 (.0355868)
Average fraction of skilled employees 1997-2000	.187516 (.4436583)	.0428748 (.1001782)
Average fraction of unskilled employees 1997-2000	.0424639 (.4815829)	.0022511 (.1123004)
Average fraction of part-time employees 1997-2000	-.091363 (.3730828)	-.0060608 (.091371)
Labour turnover 1997-2000	1.200811 (.7588329)	.2905585 (.1908259)
Investment in ICT 1997-2000	-.0757918 (.1803445)	-.0167778 (.0396752)
Investment in production technology 1997-2000	.3312543 * (.1805064)	.0641921 * (.0347851)
Organisational changes in 1998	-.0121613 (.1299908)	-.0052238 (.0287263)
R&D department in 1998	.2591119 ** (.1108023)	.0696695 ** (.0295431)
Technical condition of the machines in 1997	-.0096771 (.1030803)	-.001671 (.0255935)
Union contract 1997-2000	.1168214 (.119998)	.0303019 (.0291842)
Works council 1998-2000	-.0963043 (.1439883)	-.0219831 (.0374589)
Real innovation in 1998	.4630527 *** (.108602)	.1412073 *** (.036007)
Founding year	.0139797 (.1149511)	.0050596 (.0290037)
Log Average fraction of employees on population 1997-2001	.1320533 (.1484004)	.0354316 (.0369103)
West Germany	-.1674628 (.1053497)	-.0438296 (.0274118)
Industry dummies	Yes	Yes
	Number of observations 1.174 *McFadden R2* 0.0761 *Count R2* 0.815 *Adjusted Count R2* 0.023 *Hosmer Lemeshow chi2* 6.84 *Prob>chi2* 0.554	*Number of observations* 1.189 *F(39, 1149)* 4.98 *Prob > F* 0.0000 *R-squared* 0.0738 *Root MSE* .38148

It turns out that already in our simple multivariate regression framework continuous training cannot explain the success of the radical innovators. However, the existence of a research and development department still exhibits a strongly positive effect on radical innovations. We suggest that high qualified employees working in research and development are permanently confronted by new challenges and thus have to increase and adapt their existing knowledge stock all along. This kind of knowledge formation, however, might not appear in the survey answers of the training question. This might be the reason for training having no effect. Still, we do not know what kind of knowledge management it is exactly that distinguishes successful from less successful research and development departments.

Aside from a research and development department, former radical innovations, and investment in production technology, no significant independent variable can be found in the probit model as well as in the linear probability regression model presented in Table 6. Obviously, radical innovations are caused by factors other than the factors, which are responsible for imitation or product/service enhancement activities. So far, we do not know more about these factors. Accordingly, the goodness of fit of these last models is called into question by the listed test statistics.

6. Conclusion

The goal of our paper was to test the hypothesis that continuous training is a necessary condition for successful innovation. Following Aghion *et al.* (2006), we argue that innovation is the only way for a firm to prevent entry and overcome competition. Therefore, incumbents must innovate constantly if they do not want to risk losing their position in the market, along with the accompanying rents. However, the necessity to innovate successfully inhibits incumbents from undertaking risky and adventuresome innovations; instead, they rely on routinized innovation. This, in turn, creates a demand for a firm-internal knowledge stock comprised of knowledge based in former experience, which is embodied in the workforce, *and* the latest technological knowledge, along with the skills necessary for its successful implementation. Ensuring that the knowledge stock contains appropriate amounts of both types of knowledge can be achieved through moderate turnover in the labor force along with continuous training in the latest technology. Accordingly, we assume that firms operating successfully at the technology frontier and innovating constantly must rely on continuous training because routinized innovations do not come out of thin air.

Empirically, we test our hypothesis that continuous training supports innovation by employing German micro-level panel data. In a simple multivariate regression framework, we find evidence that continuous training does have a positive effect on a firm’s innovative ability. In the case of radical innovation, we do not find this positive correlation. However, when instrumenting continuous training by the existence of a union contract and a works council, the positive impact of continuous training on innovation disappears, although both instruments prove to be valid.

This finding can be interpreted in two ways—both having important policy implications. First, the results can be interpreted in a way that continuous training does not have a positive impact on innovation. This interpretation challenges the currently prevailing training programs such that politicians along with managers should think about a reconceptualization. Second, the results can be interpreted in a way that continuous training in general does have a positive impact on innovation; however, it is not the kind of training which is induced by union contracts and works councils that stimulates innovative activities. In this second case, apparently, the regulations and recommendations of unions and works councils encourage a sort of training which is on average not beneficial in terms of a firm's dynamic innovative activities. This raises the interesting questions: Do these institutions merely react passively to secure employment of the incumbent workers? How could these institutions act proactively in support of a firm's innovations?

In a way, our results are unsatisfactory, as we can not answer the question whether there are kinds of training which are beneficial in terms of a firm’s innovative activities. What we can say is that it is obviously not the kind of training induced by union contracts and works councils. However, these results suggest the value of further study on the kind of training that could have an impact on firms’ innovations.

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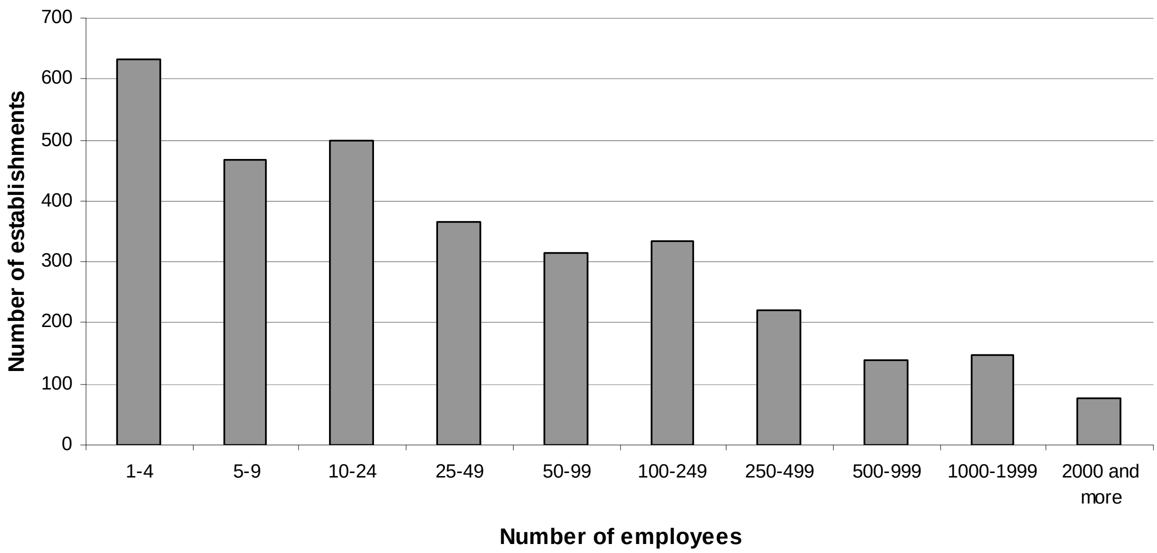
Appendix 1: Distribution of establishments across industries

Industry	Freq.	Percent
Agriculture and forestry	156	4.88
Energy, mining, water supply	83	2.60
Chemical industry, petroleum processing	51	1.59
Plastics, rubber industry	28	0.88
Earths, stones and fine ceramics industry	63	1.97
Iron, steel and metal industry	96	3.00
(Light) Metal construction	182	5.69
Electrical engineering, data processing machines	117	3.66
Road vehicle manufacturing, garages	90	2.81
Shipbuilding, aircraft construction	12	0.38
Fine mechanics, toys industry	65	2.03
Wood working	69	2.16
Paper and printing industry	47	1.47
Textile industry	48	1.50
Food, beverages and tobacco industry	122	3.81
Building industry	427	13.35
Trade	552	17.26
Communications and information transmission	172	5.38
Credit institutions	98	3.06
Insurance industry	48	1.50
Real estate services	63	1.97
Restaurants, accomodation services	167	5.22
Other Services	442	13.82
Total	3,198	100.00

Appendix 2: Distribution of establishments across size classes



Appendix 3: Summary descriptive statistics on dummy independent variables

Independent variable		Freq.	Percent	Independent variable		Freq.	Percent
Investment in ICT 1997-2000	No	727	22.84	Union contract 1997-2000	No	1,649	51.56
	Yes	2,456	77.16		Yes	1,535	48.00
	Total	3,183	100.00		Total	3,184	100.00
Investment in production	No	632	19.86	Works council 1998-2000	No	2,102	66.71
	Yes	2,551	80.14		Yes	1,049	33.29
	Total	3,183	100.00		Total	3,151	100.00
Organisational changes	No	1,142	36.06	Some innovation in 1998	No	1,615	50.74
	Yes	2,025	63.94		Yes	1,568	49.26
	Total	3,167	100.00		Total	3,183	100.00
R&D department in 1998	No	2,594	81.24	Founding year	Before 1990	1,930	60.62
	Yes	599	18.76		1990 or after	1,254	39.38
	Total	3,193	100.00		Total	3,184	100.00
Technical condition of the machines in 1997	Middle/old	991	31.08	East or West Germany	East	1,626	50.84
	Cutting-edge/new	2,198	68.92		West	1,572	49.16
	Total	3,189	100.00		Total	3,198	100.00

Appendix 4: Summary descriptive statistics on metric independent variables

Independent variable	Observations	Mean	Std. Dev.	Min	Max
Average number of employees 1997-2000	3,198	277.6542	1,272.58	1	43,857.25
Average fraction of skilled employees 1997-2000	3,190	.6161419	.2607177	0	1
Average fraction of unskilled employees 1997-2000	3,190	.2100377	.2321988	0	1
Average fraction of part-time employees 1997-2000	3,151	.1366122	.1929663	0	1
Labor turnover 1997-2000	3,147	.0601174	.070666	0	.6428571
Average fraction of employees on population 1997-2001	3,195	.3300649	.1051249	.1131106	.8199473