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Another piece of the puzzle: Firms' investment in training as optimization of skills inventory

Harald Pfeifer and Uschi Backes-Gellner

Universität Zürich
IBW – Institut für Betriebswirtschaftslehre

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Another piece of the puzzle: Firms' investment in training as optimization of skills inventory[1]

Harald Pfeifer[2]

Uschi Backes-Gellner[3]

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[2] Prof. Dr. Harald Pfeifer, Federal Institute for Vocational Education and Training, Germany. Telephone: +4922 8107 1335; e-mail: harald.pfeifer@bibb.de. Address: Robert-Schuman-Platz 3, D-53175 Bonn, Germany.
[3] Prof. Dr. Uschi Backes-Gellner, University of Zurich, Switzerland. Telephone: +4144 634 4281; email: backes-gellner@business.uzh.ch. Address: Plattenstrasse 14, CH-8032 Zurich, Switzerland.

Abstract

Background

By applying the inventory theory to hiring skilled workers under uncertainty, the authors explain how firms decide on their optimum investment in an "inventory of skills." This paper investigates the conditions under which firms are willing to make investments in a skilled workforce themselves rather than relying on skills produced within the education system or by other companies. By applying inventory theory to investments into apprenticeship training, the authors explain how firms decide on producing an optimum "inventory of skills" today to meet future demand. The authors derive hypotheses on how much firms are willing to invest in having a larger inventory of skilled worker depending on different types of inventory costs (overage cost, underage costs, demand structure).

Methods

The authors use data from the BIBB Cost-Benefit-Survey 2012/2013, which comprises detailed information on different costs and benefits of training investments from the firm's perspective. The study applies a negative binomial estimation model.

Results

Results are threefold: firms are willing to invest in a larger inventory of skilled workers, i.e., to train more apprentices, first, if the costs of producing and retaining an excessive number of skilled workers (overage costs) are lower, second, if the costs of being short of skilled workers (underage costs) are higher, and third, given an identical cost structure, if it is more likely that the demand for skilled worker may be high in the future. Even more important is the relationship of the three: the combination of a firm's critical ratio (underage costs in relation to overage costs) with its demand structure (industry volatility) is associated with a higher inventory of skills.

Conclusion

The findings (particularly the relation of underage and overage costs, in combination with the demand structure) have important policy implications for firms' incentives to invest in apprenticeship training.

Keywords

Vocational education and training (VET), inventory decision, overage and underage costs, demand structure

Introduction

Firms have to decide in advance on how many unskilled workers, e.g. apprentices, they will train to meet an expected future demand for skilled workers who complete tasks independently and well. We argue that a firm decides on the optimal production of skilled workers by minimizing two opposing costs—overage (too much inventory of skills) and underage (not enough inventory of skills)—given an anticipated future labor market situation.

Previous studies focused on the one hand side on discounted (net) training costs and showed that an excessive inventory of skilled workers can cause both obsolescence of skills and a total loss of training investment if trained workers leave the firm (e.g., Muehlemann et al. 2007; Wolter and Ryan 2011). Previous studies on the other hand side focused on the benefits of internally trained workers (e.g., Winkelmann 1996; Wolter 2008; Mohrenweiser and Backes-Gellner 2010; Muehlemann et al. 2010; Blatter et al. 2012; Blatter et al. 2016; Muehlemann and Pfeifer 2016). However, the second group of studies neglected the possibility of a shortage of skilled workers. A shortage would cause missed business opportunities and potentially lost sales, thereby leading to higher underage costs. Previous studies did not take into account the "expected demand”, which has been modelled first by Harris (1913) in his inventory decision model. This model, usually applied to warehouse stock, shows that all three components—overage costs, underage costs, and expected demand—are the drivers for firms' decision as to when to invest in an inventory of goods; likewise the three components are the drivers for firms' decisions to invest in training to meet future needs rather than relying on externally trained workers when future needs are already prevalent. Backes-Gellner (1996) was the first to apply an inventory model and its components to apprenticeship training. We draw on the hypothesis developed in her study and use more detailed information on firms' costs to empirically show how firms make their training decisions. The paper adds to the literature by using a comprehensive empirical analysis of firms' training decisions, factoring in the three components of overage costs, underage costs, and the demand structure. Apprenticeship training in Germany makes an excellent empirical case because detailed firm-level data on the different costs and benefits of training apprentices is available from Cost-Benefit-Surveys (BIBB CBS).

Background

The inventory model

The inventory theory helps to minimize costs of warehouse stock given the relevant market situation (Harris 1913)[a]. To investigate the firms' decisions on producing skilled workers, we apply a model from the inventory theory to apprenticeship training. This model assumes that firms decide in advance on how much inventory of skilled workers to produce. Moreover, firms are bound to their decision for the training period of approximately three years, the expected demand for skills cannot be predicted with certainty, and firms face some probability to end up with too many or not enough apprentices in the future. Furthermore, the classical inventory model assumes that holding costs are proportional to the quantity and time of goods in inventory and that ordering costs are fixed as well as decreasing with quantity (Erlenkotter 1990).

The inventory model considers the overage costs, underage costs, the underlying demand structure, as well as the interaction of these fundamental determinants—and is therefore ideal to analyze our research question[b]:

$$A^* = f\,(OC, UC, DS, DSxCR), \text{ with}$$

A*: optimal inventory of skills, i.e., optimal number of apprentices,

OC: overage costs,

UC: underage costs,

CR: critical ratio,

DS: demand structure.

We explain these components in the following section.

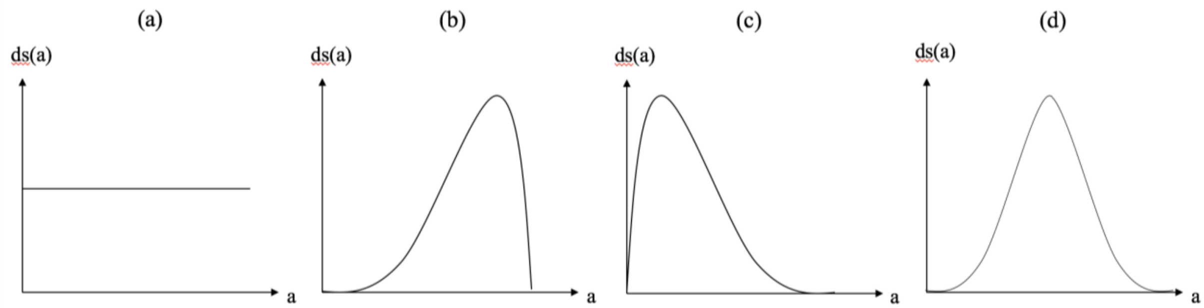
Overage Costs, Underage Costs, and Demand Structure

To begin with, overage costs originate from firms training apprentices internally that they may or may not need in the future. Producing skilled workers requires time and money. If a firm trains too many apprentices, either it is stuck with inventory, thereby facing storage costs such as wage, or it encounters trained apprentices leaving (Cappelli 2008). Therefore, if firms overshoot demand, they face costs of having excess inventory. Since expected costs of a surplus increase monotonically with increasing inventory, we expect a firm's overage costs to be negatively related to the level of skills inventory held (Backes-Gellner 1996).

In contrast, underage costs derive from not having enough skilled workers (or trained apprentices) available when needed. Consuming trained apprentices beyond built inventories makes the firm experience delays and deficiencies, thus causing lost business opportunities unless the firm finds substitute workers in due time (Cappelli 2008). Hiring skilled workers from the external labor market brings its own costs, though, which are comparable to ordering costs of inventory. Therefore, if firms undershoot demand, they face a risk of being short of inventory. Since expected costs of a shortage decrease monotonically with increasing inventory, we expect a firm's underage costs to be positively related to the level of skills inventory held (Backes-Gellner 1996).

Furthermore, the demand structure represents a firm's expectations of future demand. Whereas future demand for skilled workers is unknown, the probability distribution is known. Thus, the density function in Figure 1 describes the probability that firms will actually demand the amount '*a*' of skilled workers in the future (Backes-Gellner 1996). As a simplification, we consider two opposing extremes for the probability density of skills demand: very high and very low demand expectations[c]. A positively skewed density function represents a high probability for high-expected demand for skilled workers, i.e., a high probability that many skilled workers are needed in the future (Figure 1b). In contrast, a negatively skewed density function characterizes a high probability for low expected demand for skills, i.e., a high probability that few skilled workers are needed in the future (Figure 1c)[d].

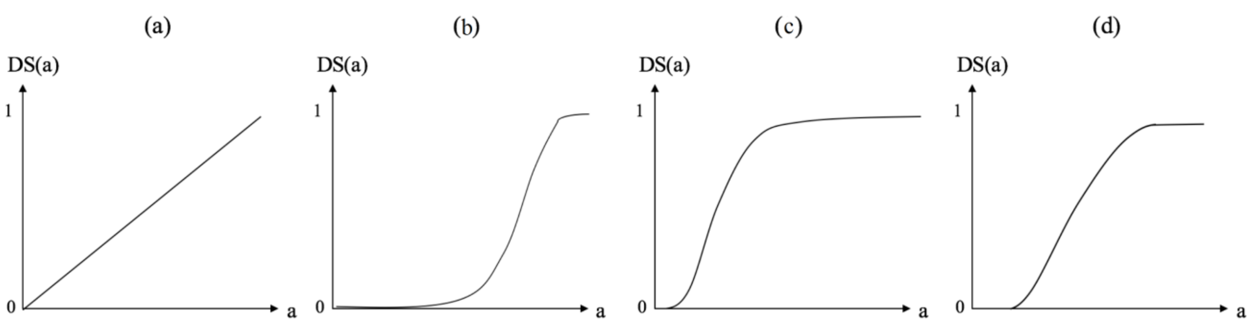
Figure 1: Characteristic demand structures



Notes: Figure 1 shows characteristic demand structures for (a) uniform, (b) high, (c) low, and (d) medium future expected demand of skills (with a: level of skills inventory, and ds(a): density function of demand for specific level of skilled workers).
Source: Authors' illustration, in line with Backes-Gellner (1996).

Accordingly, the distribution function in Figure 2 shows the cumulative demand of skilled workers (Backes-Gellner 1996).

Figure 2: Characteristic cumulative demand



Notes: Figure 2 shows characteristic cumulative demand for (a) uniform, (b) high, (c) low, and (d) medium future expected demand of skills (with a: level of skills inventory, and ds(a): distribution function of demand for specific level of skilled workers).
Source: Authors' illustration, in line with Backes-Gellner (1996).

Optimal Inventory

The optimal inventory level is calculated by minimizing the expected sum of the two specified cost components, overage costs and underage costs, given the demand structure. Total costs are a stochastic variable C(D,a) with the following properties (Backes-Gellner 1996):

$$C(D, a) = OC \max(0, a - D) + UC \max(0, D - a)$$

where a firm ends up with overage costs (OC) if it has trained more apprentices than demanded, and underage costs (UC) if it demands more apprentices than trained.

To deduct hypotheses for a firm's optimal inventory strategy, we assume cost minimization as optimality criterion. Thus, the specific amount 'a*' of skills inventory minimizes the expected value of underage costs and overage costs[e]:

$$DS(a^*) = \frac{1}{1+\frac{OC}{UC}} = \frac{UC}{UC+OC} = CR, \text{ with}$$

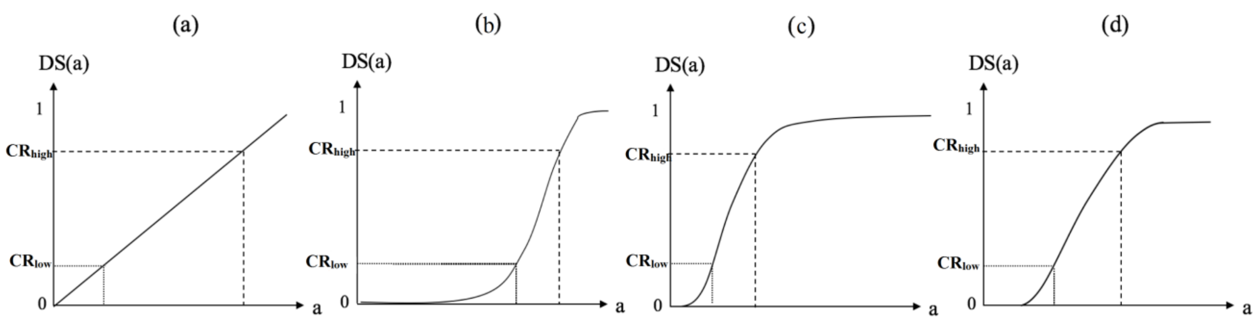
D: demand for skilled workers, a: level of skills inventory, i.e., number of apprentices, DS(a): distribution function of the demand for qualificationsf, i.e., the probability that skilled workers are actually needed in the future, OC: overage costs, UC: underage costs, CR: critical ratio.

Consequently, the optimal inventory level depends on the assumed distribution function of demand as well as on the relation of a firm's overage (OC) and underage costs (UC), as expressed by the critical ratio (CR). A high critical ratio results from high underage costs or from low overage costs, i.e., if underage costs are relatively high compared to overage costs (Figure 3, dashed line). By contrast, a low critical ratio results from low underage costs or from high overage costs, i.e., underage costs are relatively low compared to overage costs (Figure 3, dotted line).

Hypotheses

Generally, we expect a firm to build a higher skills inventory by training apprentices if overage costs are relatively low compared to underage costs, i.e., in case of a high critical ratio. However, Figure 3 shows that firms may provide little training despite low overage costs (and thus, a high critical ratio) if they expect future demand to be low, or that firms may provide much training despite high overage costs (and thus, a low critical ratio) if they expect future demand to be high. In fact, we find the optimal level of skills inventory for both, low and high demand expectations, by identifying the x-axis value for a specific critical ratio on the y-axis of the distribution function of skills demand. Overall, the critical ratio (e.g., high underage costs compared to overage costs) together with the demand structure (e.g., high expected demand) have a positive, enhancing effect on the inventory of skills.

Figure 3: Characteristic cumulative demand for given critical ratios



Notes: Figure 3 shows characteristic cumulative demand for (a) uniform, (b) high, (c) low, and (d) medium future expected demand of skills (with a: level of skills inventory, and ds(a): distribution function of demand for specific level of skilled workers, CRH: UC > OC and CRL: UC < OC).
Source: Authors' authors' illustration, in line with Backes-Gellner (1996).

We formulate the following hypotheses on the optimal number of apprentices in a firm (analogous to Backes-Gellner 1996):

H1: The lower a firm's overage costs given equal underage costs, the higher is c.p. its investment in an inventory of skilled workers, i.e., the more apprentices it trains.

H2: The lower a firm's underage costs given equal overage costs, the lower is c.p. its investment in an inventory of skilled workers, i.e., the less apprentices it trains.

H3: Given an identical cost structure, the higher the probability that a firm has a high expected demand for skilled workers, the higher is its investment in an inventory of skilled workers, i.e., the more apprentices it trains.

H4: The effect of a higher probability of need for skilled workers on the investment in an inventory of skilled workers is even larger for a high critical ratio, i.e., the number of apprentices does not only depend on the expected demand but much more on its combination with the relation of underage to overage costs.

To sum up, we investigate how the training intensity, i.e. the optimal inventory level, depends on a firm's overage costs, underage costs, demand structure as well as the combinations of these three.

The German apprenticeship training

The apprenticeship system (in Germany[g], Switzerland and Austria) allows the firms to produce skilled workers and to manage their inventory of skills according to their needs. In other words, firms decide on the number of apprentices they train depending on their overage costs, underage costs, and their expected demand.[h]

In Germany, the apprentices spend about 70-80% of their time on-the-job, where the firm trains them according to the training curricula of one of the 320 registered occupations (BIBB 2016). Therefore, apprentices acquire skills relevant for their occupation and get integrated in the production process of the firm. In addition, apprentices visit vocational schools. After 2 - 3.5 years, apprentices complete an external exam that is nationally recognized, allowing them to work as a skilled worker anywhere in the respective occupation. Subsequent to the training, the firm decides whether to make an offer for retention, which the apprentice then can accept or not. The apprenticeship system thus enables the firms to decide on the number of skilled workers they would like to train. The choice on how many apprentices to train depends on the different components of costs and the expected demand for skilled workers.[i]

Operationalization of variables

As our dependent variable, we use the *Number of Apprentices* presently trained in a firm, which is a count variable bounded at zero and has a strongly skewed distribution. We take the absolute number rather than a ratio and simultaneously control for firm size.

The independent variable *Overage Costs* originates from training (and retaining) apprentices internally. In the context of apprenticeship training, overage costs (per apprentice) include three main components.

First, set-up costs are the net costs that a firm invests to train its apprentices. *Net Training Costs* in Euros include the average gross costs, e.g., costs for apprentices (wages), costs for trainers, physical costs and other costs, minus the corresponding benefits such as productive contribution of apprentices during their training[j]. Net training costs can be positive (i.e., a net investment) or negative (i.e., a net benefit). Empirically, non-training firms might not train apprentices because of significantly higher net training costs in contrast to training firms (Wolter et al. 2006). Therefore, training costs for non-training firms would systematically differ if these firms were to switch to a training policy. Muehlemann et al. (2010) provide a solution to this problem by using selection models to investigate the potential costs and benefits of non-training firms. Analogously, we estimate training costs for non-training firms with identical selection models and the same exclusion restriction, i.e., availability of skilled workers[k]. Subsequently, we multiply these net training costs per year and per apprentice by the *Training Duration* for a specific training occupation in years (ranging from 2 to 3.5 years) to calculate the net training costs for the whole training duration of one apprentice.

Second, walk-away costs are the costs associated with the full loss of investment if a self-trained worker leaves to join another firm. In this context, the *Retention Risk* represents the expected percentage of apprentices that leave voluntarily or involuntarily, compared to the number of stayers per firm. To account for this full loss, firms must train more "supplementary" apprentices to begin with. We thus add the observed leaving percentage to the overall investment costs in training. And third, obsolescence is the process of skills becoming outdated over time, thus leading to a partial loss of investment. This loss would add up onto the overage costs. However, we do not account for obsolescence in our overage costs because of the chosen time frame as well as difficulties in measuring the actual loss. In addition, these costs are not common in reality: apprentices either leave the firm or are taken over to do work.

The independent variable *Underage Costs* derives from not having enough skilled workers (or trained apprentices) available when needed. In the context of apprenticeship training, underage costs (per position) include the following three components.

First, *Outage Costs* represent the lack of skilled employees leading to delays and deficiencies, which in turn cause lost business opportunities both in the short and long run. We estimate this loss of sales by means of the value added, i.e., sales output minus input, per employee as an average per region (federal state) and industry and for the vacancy time during which a skilled worker is missing. Subsequently, we multiply these outage costs per year and per position by the *Vacancy Duration* in years (ranging from 0.01 to 1.13 years) to calculate the outage costs for the expected duration of the vacancy for one skilled worker. We use the vacancy time on a regional (community) and occupational level as collected by the Federal Employment Office.

Second, *Hiring Costs* are the costs for hiring substitute workers from the external labor market to avoid a loss of sales. They include searching and recruiting costs as well as adjustment costs (additional training courses and productivity loss during adaptation) for each firm[l]. Analogous to the net training costs, non-hiring firms face systematically different hiring costs in contrast to hiring firms. Again, we estimate recruitment costs for non-hiring firms with the help of a selection model and an exclusion restriction (the realignment of the production[m]).

Third, miscast costs are the costs associated with an erroneous appointment of substitute workers. In this context, the *Miscast Risk* represents the expected percentage of erroneous appointments of skilled workers leaving again within one year compared to all appointments per firm. Since a miscast induces further outage costs as well as a repeated recruitment process, we adjust the costs to this additional risk.

Lastly, the independent variable *Demand Structure* represents expectations of demand for skilled workers in the future. The skills demand is a derived demand resulting from the market demand for goods produced and services performed. We use the industry volatility, i.e., the sales fluctuations per employee for a specific industry in either West or East Germany, as a proxy for a firm's production strategy and competitive situation. A high volatility thereby shows that industry sales can continuously vary on a large scale. To permanently meet the unpredictable demand for skills, workers need to be functionally flexibly employable with correspondingly high and broad qualifications[n]. Because it is difficult to replace highly specialized skills with temporary work, firms build a large inventory of skilled workers in advance by training apprentices.[o] In contrast, in case of stable market conditions (as present e.g. in the public service sector), the risk for lost business opportunities is lower since sales and underlying demand for skilled workers are comparably predictable. Therefore, these firms build a smaller inventory of skills.

Methods

Data

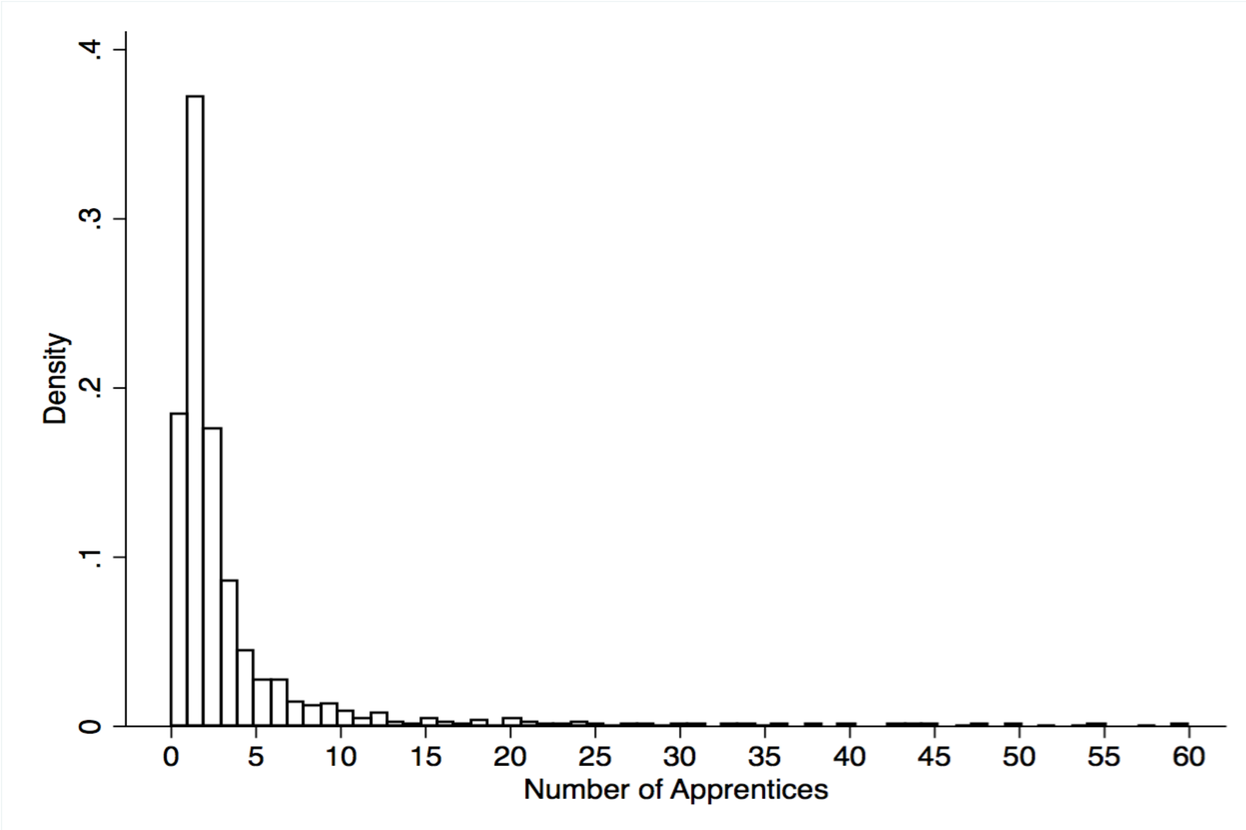
To construct the different components of our inventory model, we use the cost-benefit study from the Federal Institute for Vocational Education and Training (BIBB). This cross-sectional survey includes detailed firm-level data on different costs and benefits for 3000 training and 900 non-training firms of the training year of 2012/13[p]. The Federal Employment Agency provided the sample of firm addresses from the administrative firm register. The interviewers used the CAPI method (computer-assisted personal interview), i.e., they visited the firms in person to collect the information. The questions about the costs and benefits of training refer to one specific occupation, which was selected randomly among the trained occupations in the firm at the beginning of the interview.

Furthermore, we merge the firm-level data with aggregated register data collected by the Federal Employment Office. The data include vacancy durations on a regional (community) and occupational level to calculate the actual outage costs for the expected duration of the vacancy of a skilled worker.

Descriptive statistics

The dependent variable *Number of Apprentices* in a firm can be interpreted as a count data variable with a zero for non-training firms: in the sample (N=3,252), around 18% of the firms do not train, 36% train only one apprentice, 0.5% train more than 60 apprentices, and one firm trains 700 apprentices[q] (Figure 4). On average, a firm trains 3.9 apprentices. Considering the calibration weight for training and non-training firms in the whole population, only 27% of the firms actually train apprentices leading to an average of 0.6 apprentices per firm (and 2 apprentices per training firm).

Figure 4: Distribution of dependent variable "Number of Apprentices"



Source: BIBB CBS 2012/2013.

In Table 1, we further describe our main independent variables as well as their underlying components used for construction. First, Total *Overage Costs* amount to 23,050 Euros on average with *Net Training Costs* making up the biggest part of *Overage Costs* with a mean of 18,220 Euros (79%). Second, Total *Underage Costs* amount to 91,110 Euros on average. *Outage Costs* are by far the largest component of *Underage Costs*, with a mean of 68,400 Euros (75%). Third, regarding the *Demand Structure*, the average volatility of sales is around 4.5 m Euros. Sales per employee fluctuate from minimum 24,000 to maximum 21.7 m Euros depending on industry and region.

Overall, underage costs are remarkably higher than overage costs. Underage costs are also much higher than assumed in previous literature because outage costs, which make up to 75% of total underage costs, have either been tremendously underestimated or completely neglected so far.

Table 1: Descriptive statistics — Overview (Full sample)

Variable	Mean	St. Dev.	Min.	Max.
Number of Apprentices (per firm)	0.57	4.40	0	700
Overage Costs				
Total Overage Costs[i)]	2.305	2.132	-12.599	25.862
Net Training Costs	1.822	1.693	-9.447	20.463
Retention Risk	0.27	0.09	0.04	0.65
Underage Costs				
Total Underage Costs[ii)]	9.111	48.866	-0.832	1610.237
Hiring Costs	0.864	0.941	-0.510	16.658
Outage Costs	6.840	41.198	-1.349	1371.456
Miscast Risk	0.18	0.05	0.11	1.053
Demand Structure				
Industry Volatility	4.50	7.23	0.02	21.67
Controls				
Firm's Size (in #employees)	20.96	172.99	1	25,341
Firm's Age (in years)	29.70	47.37	1	919
Collective Agreements (binary)	0.35	0.48	0	1
Worker Representation (binary)	0.17	0.37	0	1
Training Occupation	9 different groups of training occupations			
Federal State	16 different federal states (regions)			
Number of observations	3252 observations			

*Notes: Table reports all costs in 10000 Euros per person with i) Total Overage Costs = Net Training Costs * (1+Retention Risk), and ii) Total Underage Costs = (Hiring Costs + Outage Costs)* (1+Miscast Risk). Source: BIBB CBS 2012/2013.*

In Table 2, we report our two cost variables for different subgroups. Whereas overage costs hardly differ for training and non-training firms[r], underage costs are much higher for training firms. Comparatively high underage costs are a potential reason for training as firms can avoid underage costs by hiring trained apprentices as skilled workers. Remarkably, even if underage costs are on average (much) higher than overage costs, some firms do not train. These firms may either discount the future (especially prospective benefits) a lot or they may not consider the long-term perspective of their optimal inventory strategy at all.

Table 2: Descriptive statistics — Details (Subsamples)

	Total Overage Costs	Total Underage Costs	Number of Observations
Training	2.177	13.473	2658
Non-training	2.351	7.527	594
Firm's Size (up to 9 employees)	2.360	9.522	970
Firm's Size (10 to 49 employees)	2.027	8.057	1267
Firm's Size (50 to 499 employees)	2.625	7.057	822
Firm's Size (more than 500 employees)	2.836	11.554	193
Firm's Age (up to 10 years old)	2.390	8.610	706
Firm's Age (11 to 20 years old)	2.548	7.056	799
Firm's Age (21 to 50 years old)	2.226	6.591	940
Firm's Age (more than 51 years old)	1.774	18.686	807
Collective Agreements	2.394	7.855	1592
No Collective Agreements	2.256	9.791	1660
Worker Representation	2.854	5.331	1152
No Worker Representation	2.195	9.865	2100
Training occupation in agriculture, forestry, farming, and gardening	0.664	25.529	78
Training occupation in production of raw materials and goods, and manufacturing	2.401	8.353	828
Training occupation in construction, architecture, surveying and technical building services	3.182	10.327	254
Training occupation in natural sciences, geography and informatics	3.730	3.735	104
Training occupation in traffic, logistics, safety and security	2.281	2.434	195
Training occupation in commercial services, trading, sales, the hotel business and tourism	1.752	2.885	679
Training occupation in business organization, accounting, law and administration	2.319	21.212	756
Training occupation in health care, the social sector, teaching and education	2.047	3.978	305
Training occupation in philology, literature, humanities, social sciences, economics, media, art, culture, and design	4.363	5.579	53
Region: West	2.233	10.510	2617
Region: East	2.605	3.286	635

*Notes: Table reports all costs at mean in 10000 Euros per person with i) Total Overage Costs = Net Training Costs * (1+Retention Risk), and ii) Total Underage Costs = (Hiring Costs + Outage Costs)* (1+Miscast Risk). Source: BIBB CBS 2012/2013.*

Econometric modelling

Figure 4 shows that our dependent variable, the number of apprentices, is a count outcome with a strongly skewed distribution and a limited range of values (Cameron and Trivedi 2013). Accordingly, we aim for an estimation procedure that accounts for the Poisson-like distribution of the form $\Pr\{Y = y\} = \frac{e^{-\mu}\,\mu^{y}}{y!}$, where y is the observed number of counts and μ is the mean of the Poisson distribution, implying $E(y_i|x_i) = Var(y_i|x_i)$. More specifically, we use a negative binomial regression due to the incidence of overdispersion (Wooldridge 2010). The estimated model has the form

$$y_i = \exp(\beta_0 + \sum_{j=0}^{K} \beta_j\, x_{ij} + \varepsilon_i),$$

where the intercept β_0 and the independent variables $\beta_j x_{ij}$ determine the number of counts y_i. While the overage costs, underage costs and the demand structure for the firm are our main independent variables x_i, we use the number of apprentices in firm *i* as dependent variable y_i.

We control for a set of variables including *Federal State* (16), *Training occupation* on the 1st-digit level (9) and the *Firm's Age* (Majumdar 2007; Muehlemann et al. 2010; Czepek et al. 2015; Zika et al. 2015). Furthermore, we control for *Firm Size* categories to account for potential institutional and production technology differences between firms of different sizes (e.g., employment protection legislation). Because in Germany, firm- and sector-level institutions are important determinants of the training participation (Kriechel et al. 2014), we additionally control for the presence of a *Worker Representation* at the firm level, e.g., works council, as well as for *Collective Agreements* negotiated at sector level.[s] Finally, we use the number of employees in firm *i* as the exposure variable in the model.[t] By including the exposure variable, we technically regress the number of apprentices per employee in the firm (i.e., the apprentice rate) on the independent variables[u].

Results and Discussion

The tables in this section provide the original coefficients of the negative binomial regression estimators. Because the interpretation of the coefficients is not straightforward, we further supply percentage changes that are calculated by estimating the incidence-rate ratios (IRR).

Table 3 shows the negative binominal regression with the Number of Apprentices as our dependent variable, and Overage Costs, Underage Costs and Demand Structure as the main explanatory variables. Column 1 provides estimates of the baseline model and Column 2 the model including the full set of structural and institutional variables. The estimates in Column 2 show that the overage costs are negatively related to the number of apprentices in a firm. An increase of one unit (i.e., 10.000 Euro) in the overage costs leads to a decrease in the number of trained apprentices of 4.1 percent. An increase in one unit of the underage costs, on the contrary, is associated with an increase of apprentices by about 0.1 percent—a small but still significant value. Furthermore, our proxy for the probability that firms have a high expected demand for highly skilled workers—the industry volatility—is positively related to the inventory of apprentices: an industry that is more volatile by one unit (1m Euro) is associated with an increase in the number of apprentices of 2.2 percent, which is a lot considering industry volatility reaching from 0 to 22m Euro.

Finally, as displayed in Column 3, the demand structure in combination with the critical ratio (UC/UC+OC) is positive and significant, indicating that the relation between the critical ratio and the number of trained apprentices in a firm is stronger if industry volatility is higher. In contrast, the critical ratio alone is of little importance.

Table 3: Main Determinants of the Training Intensity (Optimal Inventory Level)

	OC UC DS			Interaction CR DS	
	(1)	(2)	%-change	(3)	%-change
Overage Costs					
Total Overage Costs	-0.0564***	-0.0423***	-4.14%		
	(0.018)	(0.015)			
Underage Costs					
Total Underage Costs	0.0008	0.0013*	0.13%		
	(0.001)	(0.001)			
Demand Structure					
Industry Volatility	0.0267***	0.0222**	2.25%	0.0255**	2.58%
	(0.010)	(0.010)		(0.010)	
Interaction CR DS					
Critical Ratio				-0.0004	-0.04%
				(0.000)	
Critical Ratio x Volatility				0.0001**	0.01%
				(0.000)	
Constant	-3.1725***	-4.0479***		-4.0355***	
	(0.083)	(0.487)		(0.485)	
Controls		included	included	included	included
Number of observations	3252	3252	3252	3252	3252
Pseudo R^2	0.009	0.040	0.040	0.038	0.038

*Notes: Table reports marginal effects of a negative binomial regression; all costs are in 10,000 Euros per person; %-change calculated as (incidence-rate ratio-1)x100; dependent variable: Number of Apprentices; controls: Firm's Size(in #employees) , Firm's Age (in years), Collective Agreements (binary), Worker Representation (binary), Training occupation, and Federal State; standard errors in parentheses; *statistically significant at the .10 level; ** at the .05 level; *** at the .01 level. Source: BIBB CBS 2012/2013.*

In consequence, we confirm the relationships among the variables as formulated in our four hypotheses: First, the lower a firm's overage costs, the higher is c.p. its investment in an inventory of skilled workers, i.e., the more apprentices it trains. Second, the lower a firm's underage costs, the lower is c.p. its investment in an inventory of skilled workers, i.e., the less apprentices it trains. Third, given an identical cost structure, the higher a firm's expected future demand for skilled workers, the higher is its investment in an inventory of skilled workers, i.e., the more apprentices it trains. And fourth, the relation between a high expected demand and the investment in an inventory of skilled workers is even larger for a high critical ratio, i.e., for high underage costs compared to overage costs.

To understand which factors are driving the relationship between cost indicators and inventory of skills, we provide an additional regression table including **subcomponents** of *Total Overage Cost* and *Total Underage Costs* (Table 4).

With respect to the overage cost components, both *Net Training Costs* and the *Retention Risk* prove to be important drivers for the negative relationship between overage costs and the number of apprentices shown in Table 3. Therefore, the net costs invested to train apprentices as well as a potential loss of this investment due to a movement of skilled workers to another firm are important determinants for a firm's optimal inventory strategy.

Regarding the underage costs, the main driver are the *Outage Costs,* i.e., the costs due to lost business opportunities. As opposed to *Hiring Costs*, *Outage Costs* are of greater scale and may occur over a persistent period rather than only one-time for hiring of substitute worker from the external labor market. The correspondingly large loss of sales could eventually cause a firm's failure. Thus, considering the costs of lost sales when deciding about the optimal inventory strategy is very important for a firm's (financial) survival. Finally, *Miscast Costs* contribute to the positive relationship between underage costs and the number of trained apprentices—since training apprentices and keeping them as skilled workers circumvents these miscast costs.

Table 4: Subdivided Determinants of the Training Intensity

	Euro Determinant	All Determinants	
	(1)	(2)	%-change
Overage Costs			
Net Training Costs	-0.0507***	-0.0501***	-4.88%
	(0.019)	(0.019)	
Retention Risk		-2.5653***	-92.31%
		(0.793)	
Underage Costs			
Hiring Costs	0.0098	-0.0238	-2.35%
	(0.055)	(0.053)	
Outage Costs	0.0014*	0.0019**	0.19%
	(0.001)	(0.001)	
Miscast Costs		0.7870	119.68%
		(0.514)	
Demand Structure			
Industry Volatility	0.0220**	0.0261**	2.64%
	(0.010)	(0.010)	
Constant	-4.0623***	-2.7810***	
	(0.490)	(0.665)	
Controls	included	included	included
Number of observations	3252	3252	3252
Pseudo R^2	0.040	0.044	0.044

*Notes: Table reports marginal effects of a negative binomial regression; all costs are in 10,000 Euros per person; %-change calculated as (incidence-rate ratio-1)x100; dependent variable: Number of Apprentices; controls: Firm's Size(in #employees) , Firm's Age (in years), Collective Agreements (binary), Worker Representation (binary), Training occupation, and Federal State; standard errors in parentheses; *statistically significant at the .10 level; ** at the .05 level; *** at the .01 level. Source: BIBB CBS 2012/2013.*

As an **alternative specification**, we focus on the decision on the optimal number of apprentices rather than the training decision itself (extensive margin). We thus restrict our sample to firms with at least one apprentice, i.e., training firms (intensive margin). The results in Table 5 look still similar except for *Underage Costs*, which still show the same sign but are less important[v]. The reason for this finding could be that these firms have already decided to train apprentices in the first place.

Table 5: Main Determinants of the Training Intensity for Training-Firms

	OC UC DS		Interaction CR DS	
	(1)	%-change	(2)	%-change
Overage Costs				
Total Overage Costs	-0.0258***	-2.55%		
	(0.005)			
Underage Costs				
Total Underage Costs	0.0002	0.02%		
	(0.000)			
Demand Structure				
Industry Volatility	0.0149***	1.51%	0.0156***	1.57%
	(0.003)		(0.003)	
Interaction CR DS				
Critical Ratio			0.0003*	0.03%
			(0.000)	
Critical Ratio x Volatility			0.00004***	0.00%
			(0.000)	
Constant	-1.9350***		-1.9155***	
	(0.100)		(0.096)	
Controls	included	included	included	included
Number of observations	2658	2658	2658	2658
Pseudo R^2	0.144	0.144	0.141	0.141

*Notes: Table reports marginal effects of a negative binomial regression for training-firms; all costs are in 10,000 Euros per person; %-change calculated as (incidence-rate ratio-1)x100; dependent variable: Number of Apprentices; controls: Firm's Size(in #employees) , Firm's Age (in years), Collective Agreements (binary), Worker Representation (binary), Training occupation, and Federal State; standard errors in parentheses; *statistically significant at the .10 level; ** at the .05 level; *** at the .01 level. Source: BIBB CBS 2012/2013.*

Moreover, we focus on firms with *Collective Agreements* because they face pre-determined wages (for apprentices, instructors, recruiters, etc.), which generally make up for most of the costs. Thus, we assume their costs to be exogenous. The results still hold for the subsample of firms with collective agreements (Table 6). However, the interaction of the demand structure with the critical ratio is not significant anymore and has thus no enhancing relation to the inventory of skills. Overall, we find that our results are rather robust to different specifications.

Table 6: Main Determinants of the Training Intensity for Firms with Collective Agreements

	OC UC DS		Interaction CR DS	
	(1)	%-change	(2)	%-change
Overage Costs				
Total Overage Costs	-0.0654***	-6.33%		
	(0.017)			
Underage Costs				
Total Underage Costs	0.0012*	0.12%		
	(0.001)			
Demand Structure				
Industry Volatility	0.0306***	3.11%	0.0341***	3.47%
	(0.011)		(0.010)	
Interaction CR DS				
Critical Ratio			0.0440	4.50%
			(0.029)	
Critical Ratio x Volatility			-0.0020	-0.20%
			(0.001)	
Constant	-3.5745***		-3.6351***	
	(0.547)		(0.539)	
Controls			included	included
Number of observations	1592	1592	1592	1592
Pseudo R^2	0.070	0.070	0.065	0.065

*Notes: Table reports marginal effects of a negative binomial regression for firms with collective agreements; all costs are in 10,000 Euros per person; %-change calculated as (incidence-rate ratio-1)x100; dependent variable: Number of Apprentices; controls: Firm's Size(in #employees) , Firm's Age (in years), Collective Agreements (binary), Worker Representation (binary), Training occupation, and Federal State; standard errors in parentheses; *statistically significant at the .10 level; ** at the .05 level; *** at the .01 level. Source: BIBB CBS 2012/2013.*

Conclusion

In this paper, we investigate the conditions under which firms are willing to make long-term investments in a skilled workforce themselves (invest in an inventory of skilled workers) rather than relying on skilled workers produced by other companies or within the education system. We apply inventory theory to apprenticeship training to explain how firms decide on their optimal "inventory of skills" produced ahead of time to meet demand in the future. Using a negative binomial regression model, we analyze detailed information on different costs and benefits of a firm's apprenticeship training in Germany (BIBB CBS 2012).

We find that first, the lower a firm's overage costs, the higher is its investments in inventory of skilled workers. Second, the higher a firm's underage costs, the higher is its investments in inventory of skilled workers. Third, given an identical cost structure, the higher a firm's expected demand for skilled workers, i.e., the more volatile the industry with continuously changing demands, the higher is its investments in an inventory of skilled workers.

Our fourth result shows that the critical ratio, i.e. the underage costs in relation to the overage costs given the demand structure (industry volatility), is positively related to the investment in an inventory of skills[w]. That is, even if overage costs are high, firms still decide to train if underage costs are even higher. Yet, these results only hold if a firm's expected demand for skilled workers is very high. Thus, firms in more volatile markets with a potentially higher future demand for skilled workers (who are able to fulfill all kinds of different jobs) are more likely to take the risk and invest in apprenticeship training today for a potential need of skilled workers tomorrow. This finding suggests that - although it may be costly to train - in certain market situations it is even more costly "not to train".

With respect to policy implications and practical contributions, the results of this paper clearly indicate that underage costs, i.e. problems and costs due to not having enough skilled workers are much more important than previously discussed in the literature. Avoiding such costs by training in excess of current short-term demands is thus an important – so far neglected - benefit of participating in apprenticeship training. Training specialists and managers responsible for training matters in companies can use these findings in internal discussions to convince finance or operation executives regarding the benefits and participation in apprenticeship training. Educational policy makers can use the findings to underline the attractiveness of the dual system, especially for example in times when demand for apprentices or apprenticeship graduates is low in the short term, but could be higher again as soon as the economic tides turn again.

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Endnotes

[a] The inventory theory provides models that are applicable to different specifications; for an overview, see Chikán (1990, p. 107 ff.).

[b] The inventory decision itself occurs at a specific point in time. We refrain from discounting the costs due to our focus on short- and medium term effects.

[c] Generally, we assume that the demand for skills is a derived demand. The specific operationalization of high and low demand follows in the next chapter.

[d] Both probability densities can be characterized by a beta prime distribution, which enables a formal analysis of the optimal inventory level given different cost structures (Backes-Gellner 1996, p. 61-62).

[e] Backes-Gellner shows the comprehensive mathematical derivation (1996, p. 54-55).

[f] Given that OC and UC are both greater or equal to zero, a corresponding distribution function DS(a) implies a second derivation larger than zero, i.e., the equation presents a cost minimum. Furthermore, optimal level of inventory a* always exists for a continuous distribution.

[g] In general, German apprenticeship training has had a long tradition as a major upper secondary education pathway for young adults where almost 60% of a cohort of school graduates enter the "dual apprenticeship system" (DESTATIS 2015).

[h] Note that the literature discusses different training motives for firms. Most studies discuss the dichotomy of investment motive (i.e. high net-costs, high retention rate) and production motive (low or negative net-costs and low retention rate). Both motives can be integrated in the inventory model with more production-oriented firms having low Overage Costs and low (or no) Underage Costs and more investment oriented firms having high Overage Costs and high Underage Costs.

[i] The inventory model does not explicitly model the supply side of apprenticeship training. If there is a shortage of apprentice applicants this would make hiring apprentices more expensive and would thus increase the gross-costs for an apprenticeship trainee. Thus, within an inventory model these and other supply-side factors would be integrated in the recruitment costs of apprentices, which – as Wenzelmann et al. 2017 have shown - are indeed correlated with local supply-side conditions.

[j] For detailed compilation of the various costs and benefits see Jansen et al. (2015).

[k] For details and calculation methods see Muehlemann et al. (2010).

[l] For detailed compilation of the various costs and benefits see Jansen et al. (2015).

[m] For details and calculation methods see Muehlemann and Pfeifer (2016).

[n] Backes-Gellner et al. (2016) discuss the importance of functional flexibility as key HR practice in more detail.
[o] Although it would in principle be possible to use temporary work agencies to hire skilled workers, this involves an additional risk (i.e. matching) and additional costs for the firm (including higher wages, lower productivity and lower flexibility). Further, in times of tight labour markets, also temporary work agencies are likely to face supply-side restrictions and may not be able to adequately supply skilled workers.
[p] The Federal Institute for Vocational Education and Training has conducted these firm-level surveys since the 1980s (e.g., Beicht et al. 2004; Schoenfeld et. al 2010; Schoenfeld et al. 2016).
[q] The results remain the same without this firm.
[r] In Switzerland, overage costs (especially net training costs) would be much higher for non-training firms as opposed to training firms. For a comprehensive comparison of cost and benefits of German vs. Swiss apprenticeship training see Dionisius et al. (2009).
[s] Due to potential endogeneity issues, we re-estimated the models also without the collective agreement control variable. However, the results remain robust and are available upon request.
[t] Despite careful modelling and a large set of control variables, we cannot entirely rule out potential reverse causality issues with the data at hand. The results should therefore be interpreted more in a descriptive sense then in a causal manner.
[u] As described in Cameron and Trivedi (2013), an exposure variable is often used to analyze counts per unit of time, if the latter is not fixed. The reasoning is that a longer period increases the number of counts. We transfer this argument to the number of apprentices in firms because larger firms usually have more apprentices than smaller firms.
[v] For Swiss firms, Muehlemann et al. (2007) find that costs have a significant impact on the training decision but no significant influence on the number of apprentices, once the firm has decided to train.
[w] We expect firms offering other professional skills development such as traineeship or further education of employees to behave accordingly.