

# Product Markets and Industry-Specific Training

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**ABSTRACT:** We develop a product market theory that explains why firms provide their workers with skills that are sufficiently general to be potentially useful for competitors. We consider a model where firms first decide whether to invest in industry-specific human capital, then make wage offers for each others' trained employees and finally engage in imperfect product market competition. Equilibria with and without training, and multiple equilibria can emerge. If competition is sufficiently soft, firms may invest in non-specific training if others do the same. Thereby, they avoid having to pay high wages in order to attract trained workers.

**Keywords:** industry-specific training, human capital, oligopoly, turnover.

**JEL:** D42, L22, L43, L92.

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# 1 Introduction

Economists have long wondered why firms invest in *general training* that makes workers potentially more valuable for other employers. According to Becker (1964) and Mincer (1974), firms should have no incentive to bear the costs of general worker training, as the associated rents accrue fully to the employees. However, these predictions seem at odds with reality (Acemoglu and Pischke 1998, Franz and Soskice 1995, Katz and Ziderman 1990, OECD 1999). In some countries, such as Germany or Switzerland, firms voluntarily pay for apprenticeships that provide workers with general skills.<sup>1</sup> In addition, firms continually pay for on-the-job training of incumbent workers.<sup>2</sup>

Similar arguments apply with a vengeance to *industry-specific training* that is valuable for other firms in the same industry, but not outside the industry. Even though this case is intermediate between specific and fully general training, firms' incentives to provide such training would appear to be even lower than for general training. As a trained worker's knowledge is only valuable within the same industry, he is most likely to work for a competitor if he leaves a firm. Thus, not only will the trained worker be of no value for the original employer, in addition, he will strengthen the competitor.

We provide a theory of industry-specific training that is related to familiar explanations of general worker training. Typical explanations in the literature rely on labor market imperfections caused by asymmetric information.<sup>3</sup> Essentially, if present employers can observe ability or training investments

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<sup>1</sup>For instance, Bardeleben et al. (1995) calculate the net costs per apprentice per year in German industry as DM 20509 per year if fixed costs are included, and DM 9194 if they are not. A considerable part of this training is general - for instance, apprentices spend about 65 days per year in external schools and courses.

<sup>2</sup>Several recent empirical studies show that a significant part of the training is not firm-specific: Baily and Gersbach (1995), Blundell et al. (1996), Goux and Maurin (1997), Loewenstein and Spletzer (1998), Regner (1995, 1997) and Villhuber (1997, 1998).

<sup>3</sup>For a survey of such explanations see Acemoglu and Pischke (1999). These authors also discuss some alternative theories that do not rely on asymmetric information (see also Stevens (1994), Kessler and Lülkesmann (2006)).

better than potential future employers, the latter will face a lemon's problem.<sup>4</sup> As a result, it is difficult for the employee to sell herself on the job market. The original employer enjoys ex post informational monopsony power, the anticipation of which creates incentives to finance general training.

We offer an alternative explanation that relies on imperfect competition in the product market and does not involve asymmetric information. We argue in the setting of a three-stage game. In a first stage (*training stage*), two initially identical firms decide on how many workers they want to train. In a second stage (*wage-bidding stage*), firms compete through wage offers for the trained workers; workers accept the better offer. Finally, in the *product market stage*, firms engage in oligopolistic product market competition. Training and turnover decisions in the first two stages determine the distribution of trained workers and thereby product market profits: We assume that a firm's *gross profits*, that is, product-market profits excluding the costs of training and wages, depend positively on its own number of trained workers and negatively on the competitor's, as trained workers increase productivity, for instance, by reducing marginal costs.

When firms compete for trained workers in the second stage, equilibrium wages will correspond to the marginal contribution of a trained worker to gross profits, for a given total supply of workers. This marginal value has two components. First, an additional worker in the own firm has a direct positive effect, because it increases the own productivity. Second, the fact that the competitor does not employ this worker helps to increase profits because it weakens the competitor.

Our main result is that there often is a symmetric equilibrium with positive training levels. To see why, suppose all firms train. Consider the incentives of a firm to reduce its training activities and poach trained workers from the competitor instead. Intuitively, in many environments the reduc-

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<sup>4</sup>Acemoglu and Pischke (1998) deal with the case of asymmetric information about ability; Katz and Ziderman (1990) and Chang and Wang (1996) consider asymmetric information about training investments.

tion in the supply of trained workers will result in an increase in wages. Rather than paying high wages to poach workers, firms might therefore prefer to train workers to keep the ex-post wages relatively low. We call this the “wage reduction effect” of training.

Indeed, because of this wage reduction effect, a symmetric training equilibrium may exist for suitable kinds of product market competition and training technology. Two conditions are conducive to the occurrence of training. First, the environment must be such that firms do not benefit too much from escaping neck-to-neck competition, that is, a situation where both firms are equally efficient, by poaching the competitor’s worker. Otherwise, high wages would be necessary to prevent workers from leaving to the competitor. Second, gross profits of both firms must be substantially higher in a situation where both firms have the same number of trained workers compared to a situation without trained workers.

If both conditions are satisfied simultaneously, we speak of *soft competition for workers*; otherwise of *intense competition for workers*. This concept is closely related to standard notions of product market competition. For instance, intense product market competition à la Bertrand corresponds to intense competition for workers and is therefore not conducive to training: When firms interact aggressively, as in a homogeneous Bertrand oligopoly, being better than the competitor is necessary to achieve positive profits. As a result, the incentive to poach the competitor’s worker is high, so that trained workers would be able to command a high wage. Anticipating this, firms refrain from training.

Conversely, we give several examples where competition in the product market is sufficiently soft that training arises. Specifically, we show that this can be the case when firms compete in prices in a differentiated-goods market, provided differentiation is sufficiently strong and demand sufficiently high. In the working paper version (Gersbach and Schmutzler 2003), we also show that training can arise for homogeneous Cournot competition, provided the market is not too small.

Therefore cross-sectoral differences in the intensity of competition may play a role in explaining differences in training expenditures.<sup>5</sup> Similarly, the widespread perception that firms have recently become less willing to invest in training may be the result of increased product market competition. In this respect, our paper goes beyond existing theory, which assumes perfect product market competition and thus cannot use different intensities of product market competition as an explanatory variable.

Apart from the training equilibrium, an equilibrium without training may exist. When no competitor trains, the value of training for an individual firm may even be negative, so that the firms under consideration would be willing to pay to prevent their workers from training. Intuitively, this is true because trained workers can threaten to join the competitor, which would reduce the payoff of the firm that trains compared to a situation where it has not trained workers. In view of the possible occurrence of multiple equilibria, we discuss governmental intervention to move firms into the training equilibrium. This discussion suggests that cross-country differences in the extent to which such coordination mechanisms are established might explain the differences in general worker training observed in OECD (1999), Acemoglu and Pischke (1998), Booth and Snower (1996), Bassanini et al. (2005).

While our theory of industry-specific training focuses on product market imperfections and does not involve asymmetric information, it shares the feature of multiple equilibria with the models of general training that rely on asymmetric information in the labor market. It is important to point to another aspect of our paper that is familiar from other explanations of general training. Soft competition guarantees that in equilibrium turnover can be prevented at relatively low costs. Anticipating this, firms are prepared to invest in training. This feature corresponds to the idea that low expected

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<sup>5</sup>The above-mentioned study by Bardeleben et al. (1995) shows great differences in training intensities across different sectors. Net variable expenditures per worker and year differ between DM 1002.- (food industry) and DM 20,565 (chemical industry). In terms of gross expenditure, the differences are still large, ranging from DM 12,142.- (road construction) to DM 32,027 (chemical industry).

turnover is favorable to training. This argument has, for instance, been used to suggest that the presence of unions may increase training (Booth et al. 2005). Similarly, it is sometimes argued that training will be relatively low in agglomerations because poaching is too easy (Brunello and Gambarotto 2007). Finally, the fact that large firms typically offer more training than small firms has been connected to the idea that they are less vulnerable to poaching because they can offer internal careers for their employees (Bassanini et al. 2005).

However, our paper covers new ground in several respects. Most important is our focus on the interactions between labor and product markets. This not only allows us to draw a connection between the intensity of competition and training. In addition, we can show how product market competition affects wages for trained workers: Essentially, with more intense product market competition, the workers enjoy greater bargaining power and higher wages. Thus, we see our contribution not only as another theory of general worker training, but also as a step towards an integrated analysis of product and labor markets. In the following, we spell out these arguments in more detail. In section 2, we introduce the assumptions of our model. In section 3, we use two very simple examples to show how training levels might depend on the intensity of competition. Section 4 provides more general results on the topic. In section 5, we discuss policy implications. Section 6 concludes.

## 2 The Model

The structure of the model is as follows. In period 1, firms  $i = 1, 2$  simultaneously choose their human capital investment levels  $g^i \in \{0, 1, 2, \dots\}$ . Think of  $g^i$  as the number of its employees receiving training. Training a worker costs  $I > 0$  for a firm.<sup>6</sup> Denote firm  $i$ 's trained workers as  $i_1, \dots, i_m, \dots, i_{g^i}$ . At

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<sup>6</sup>As the incentive of workers to acquire capital that is not firm-specific is undisputed, we ignore the possibility of training investments by workers and deliberately assume that the entire training costs are borne by the firm.

the beginning of period 2, firm  $i$  can make individual wage offers  $w_{i,i_m}(g^i, g^j)$  for each of their own workers and  $w_{i,j_m}(g^i, g^j)$  for each of the competitor  $j$ 's workers ( $j \neq i$ ). In principle, we allow wages to differ even for individuals who have the same level of human capital or belong to the same firm.<sup>7</sup> We normalize wages of non-trained workers to zero. Further, to capture the notion that human capital is industry-specific, that is, useless outside the industry, we assume that the wage of the non-trained worker is also the reservation wage for the trained workers. After having obtained the wage offers, each employee accepts the higher offer.<sup>8</sup> Denote the number of trained workers in firm  $i$  at the end of period 2 as  $n^i$ . Employing trained workers is beneficial for the present employer; it could for instance help to reduce production costs, or to increase demand by improving product quality. We focus on cost reduction. This feeds into our modeling of product market competition in period 3 as follows.

**Assumption 1:** *For each combination  $(n^i, n^j)$  of trained workers, there exists a unique product market equilibrium with resulting gross product market profit  $\pi^i(n^i, n^j) = \pi(n^i, n^j)$  for firm  $i$ . For firms  $i = 1, 2$ ,  $\pi^i(n^i, n^j)$  is weakly increasing in  $n^i$  and weakly decreasing in  $n^j$ .*

Intuitively, the higher the number of trained workers in a firm, the greater productivity and thus the higher the market profit. The higher the number of trained workers in the competitor's firm, the higher the competitor's productivity and thus the lower the own profit.

Assumption 1 contains several implicit statements about the training technology and product market competition. To start with, note that  $\pi$  depends only on  $n^i$  and  $n^j$ , not on  $g^i$  and  $g^j$ . This has two immediate implications. First, if an employee leaves the firm, the original employer loses all the benefits generated by the human capital investment - the employee leaves

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<sup>7</sup>Here "wages" should be interpreted broadly, including any type of non-monetary benefits such as pleasant working environments, fringe benefits and flexible working hours which involve costs for the employer.

<sup>8</sup>We use a flexible tie-breaking rule: If  $w_{i,i_m} = w_{j,i_m}$ , whether the employee stays in his original firm or moves is determined by equilibrium requirements.

no traces once he has left the firm.<sup>9</sup> Second, training a worker and hiring a trained worker are perfect substitutes.<sup>10</sup> We use perfect substitutability to express the idea that human capital is not firm-specific, and we shall show later on that training can nevertheless arise in equilibrium, in spite of this assumption. Finally, note that firms are symmetric in the sense that the profit function  $\pi$  depends on  $i$  only through the number of trained workers, not through the identity of the firm.<sup>11</sup>

It will sometimes be convenient to assume  $\pi^i(n^i, n^j)$  is defined for arbitrary positive numbers, not just for integers:  $n^i \notin \mathbb{N}$  refers to situations where at least one worker works part-time. In addition, we shall suppose that  $\pi$  is differentiable. We use the following terminology:

- *Net product market profits:*  $\pi(n^i, n^j) - \text{total wage payments}$ .
- *Long-term payoff:*

$$\Pi(g^i, g^j) \equiv \pi(n^i(g^i, g^j), n^j(g^i, g^j)) - \text{total wage payments} - g^i \cdot I,$$

where  $n^i(g^i, g^j)$  denotes the equilibrium number of workers in the subgame  $(g^i, g^j)$ .<sup>12</sup>

The game structure is summarized in the Table 1.

We can treat this game as a two-period game, as all the relevant information about period 3 is contained in the reduced form profit  $\pi^i(n^i, n^j)$ . Finally, we impose an assumption on product market competition that is slightly more restrictive than Assumption 1.

**Assumption 2:**  $\pi(n, n)$  is weakly increasing in  $n$ .

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<sup>9</sup>This is compatible with the assumptions in training theories that are based on labor market imperfections.

<sup>10</sup>This assumption differs from the training literature which argues that one's own workers and competitors' workers are imperfect substitutes, because the ability of the own worker is better known.

<sup>11</sup>In other words, there are no exogenous efficiency differences.

<sup>12</sup>The notation requires that a unique subgame equilibrium exists or that the resulting net product market profits are independent of the equilibrium.



Table 1: **Game Structure**

<i>Period 1:</i>	Firms $i = 1, 2$ choose training levels $g^i$ .
<i>Period 2:</i>	(i) Firms choose wage offers. (ii) Workers choose between employers, thus determining the numbers $n^i$ of trained workers.
<i>Period 3:</i>	Product market competition results in gross profits $\pi^i(n^i, n^j)$ .

Thus, gross profits increase (weakly) if, starting from an even distribution of workers, both firms increase the number of workers by the same amount.

Finally, we introduce some useful notation. Let  $G = g^i + g^j = n^i + n^j$  denote the total number of trained workers. Then, to denote the value of an additional trained worker if the own number of trained workers is  $n^i$  and the total number is  $G$ , we write

$$v(n^i, G) = \pi(n^i + 1, G - n^i - 1) - \pi(n^i, G - n^i).$$

Note that the marginal valuation  $v(n^i, G)$  is positive for two reasons. First, the more trained workers a firm itself employs, the lower its costs and the higher its gross profits. Second, the smaller the number of trained workers employed by the competitor, the higher its costs and the higher firm  $i$ 's product market profits. We can now formulate our definition of intense competition.

**Definition 1** *Competition for trained workers is intense if*

$$v(g, 2g) > \frac{\pi(g, g) - \pi(0, 0)}{g} \text{ for all } g > 0. \quad (1)$$

*Otherwise competition for trained workers is soft.*

The definition captures a simple intuition. The marginal valuation  $v(g, 2g)$  captures the value of escaping neck-to-neck competition by poaching a worker from the competitor and therefore becoming the slightly better firm; the right-hand side is the average contribution of each of a firms' workers in

the symmetric case, compared to a symmetric situation without workers. The definition then says that the value of escaping competition ( $v(g, 2g)$ ) is higher than the value of symmetric improvement, starting from no training ( $\frac{\pi(g,g) - \pi(0,0)}{g}$ ). The definition of intense competition for trained workers is related to standard notions of competitive intensity in the product market. For instance, in the case of homogeneous Bertrand competition, the condition always holds, because firms can only earn positive profits if they are more efficient than their competitors. However, condition (1) not only reflects product market conditions, but also training technology. Intuitively, when the marginal cost effect of training is decreasing, this is likely to work against condition (1).

An important remark regarding the relationship between competition in the product and labor market is in order. In our model, firms compete in the labor market for trained workers by offering wages, i.e., there is duopsonistic price competition in the labor market. This type of competition is kept constant throughout the paper, and we vary the nature of competition in the product market.<sup>13</sup>

### 3 Motivating Examples

To gain more intuition for the conditions under which training might arise, we provide two examples which are simplified in two important respects, but can nevertheless highlight the main ideas of our general approach. First, each firm is quite unrealistically limited to training one worker at most, that is,  $g^i \in \{0, 1\}$ . Second, we choose specific numerical values for gross product market profits rather than allowing for a full-fledged model of oligopolistic competition. The numerical values are consistent with Assumptions 1 and 2, however. In our first example, they are chosen so as to reflect soft competi-

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<sup>13</sup>If firms were wage takers in the labor market, no firm would invest in training regardless of the degree of competition, as the classical argument of Becker (1964) and Mincer (1974) would apply.

tion for trained workers; in the second example, they correspond to intense competition.

### 3.1 Soft Competition for Trained Workers

#### 3.1.1 The Set-Up

Assume that gross profits are as follows:

- *Training decisions*  $g^i = 0; i = 1, 2$ : If both firms do not train, they share the market at 0.5 units of gross profits each, that is,  $\pi(0, 0) = 0.5$ .
- *Training decisions*  $g^i = 1$  for some firm,  $g^j = 0$  for the other firm: gross profits for the firm that trains are  $\pi(1, 0) = 1$ ; gross profits for the firm without a trained worker are  $\pi(0, 1) = 0.2$ .
- *Training decisions*  $g^i = 1; i = 1, 2$ : If both firms have one trained worker, profits are  $\pi(1, 1) = 0.8$ . If one firm employs both workers, gross profits are given by  $\pi(2, 0) = 1$  and  $\pi(0, 2) = 0.2$ .<sup>14</sup>

Finally, as a tie-breaking procedure we assume that the worker stays with the firm where it was trained if both firms offer the same wage.

The set-up is consistent with Assumption 1: No matter whether the competitor has trained or not, employing a trained worker increases gross profits. Similarly, gross profits are lower if the competitor employs a trained worker. Also, Assumption 2 holds: gross profits are higher when both firms have trained than when neither has. The set-up reflects soft competition in the sense of Definition 1: The profit increase from becoming more efficient than the competitor is  $v(1, 2) = 0.2$ , which is smaller than  $\pi(1, 1) - \pi(0, 0) = 0.3$ , the profit increase from moving from a situation without training to a situation with symmetric training.

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<sup>14</sup>The only value of hiring a second trained worker is thus that the competitor cannot take advantage of him. Hence, if one firm employs both trained workers, its payoffs are the same as in the case with one trained worker.

### 3.1.2 The Training Equilibrium

With product market competition reduced to six possible outcomes, we can restrict attention to training and wage decisions and solve the game by backward induction. Intuitively, bidding in the labor market at stage 2 entails wages equal to the minimum of the two firms' marginal valuations for a worker.

If only one worker has been trained, the firm that employs him, say firm 1, has profits 1; if he works for the competitor, the gross profit falls to 0.2. Hence, both firms have a marginal valuation of  $v(1, 2) = 0.8$  for the worker, so that the wage, which we denote as  $w^1$ , is 0.8.<sup>15</sup>

If both firms have trained one worker, their gross profits are 0.8; if the competitor were to employ the worker, profits would drop to 0.2. Thus, the marginal valuation  $v(0, 2)$  for having one of the workers (rather than none) is 0.6. However, the marginal valuation  $v(1, 2)$  for having two workers rather than one is much lower: Hiring a second worker would increase profits from 0.8 to 1. Hence, denoting the equilibrium wage offered by both firms to each worker as  $w^2$ , we obtain  $w^2 = 0.2 = 1 - 0.8$ , and both trained workers will stay with their original firm. Importantly, training therefore not only affects gross profits, but also wages. When more workers are trained, the wage level is lower. This is the *wage reduction effect*.

With the second-period wages determined in this fashion, the game can be reduced to the simple matrix given in Table 2; where T corresponds to the case that the firm employs a trained worker and NT to the case that he does not.  $I$  corresponds to training costs.

Table 2: **Soft Competition Example**

	T	NT
T	$0.8 - w^2 - I, 0.8 - w^2 - I$	$1 - w^1 - I, 0.2$
NT	$0.2, 1 - w^1 - I$	$0.5, 0.5$

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<sup>15</sup>In the more general notation of Section 2, this would read  $w_{11}(1, 0) = w_{21}(1, 0) = 0.8$ .

The first observation confirms the intuition that the provision of industry-specific training cannot be taken for granted.

**Observation 1** *An equilibrium without training exists for all  $I \geq 0$ .*

In fact, the following stronger statement holds.

**Observation 2** *For all  $I \geq 0$ , if only one firm trains, both firms are worse off than without training.*

Essentially, the trained worker, who gets  $w^1 = 0.8$ , extracts the entire difference between the gross profits of a firm that has a trained worker and the profits of a firm that has none. The firm that has not trained ends up with long-term payoffs  $\pi(0, 1) = 0.2$ ; the firm that has trained obtains  $\pi(1, 0) - w^1 - I = 0.2 - I$ . Clearly, the firm that has not trained is hurt by training of the other firm, because it suffers from a negative externality. More surprisingly, the firm that trains also has lower net product market profits than without training, because it will have to offer high wages to prevent poaching by the competitor.

The problem is much less pronounced when both firms have trained their workers. A training equilibrium where both firms train exists if training costs are sufficiently low.

**Observation 3** *If  $I \leq 0.4$ , a training equilibrium exists.*

The intuition is simple: Suppose one firm trains. Training by the other firm increases the supply of trained workers and lowers their wages as marginal profits from hiring more trained workers decline and the bidding game becomes less fierce. For sufficiently small training costs, this wage effect makes training by both firms an equilibrium.

The last observation indicates that it is possible that both firms are better off with training than without.

**Observation 4** *If  $I < 0.1$ , long-term payoffs of each firm are higher in the training equilibrium than in the no-training equilibrium.*

### 3.2 Intense Competition

The preceding example demonstrated that industry-specific training may be provided in equilibrium provided training costs are low. To show that soft competition is crucial for training to arise, we consider next an example that reflects a situation of intense competition for workers. This example will also help to dispel the potential misconception that an increasing number of trained workers *necessarily* leads to a fall in the wage.

To this end, we modify the above example by setting  $\pi(g^i, g^j) = 0$  except when  $g^i > g^j$ . We assume  $\pi(2, 0) = \pi(1, 0) = 1$  as before. Thus competition is intense in the Bertrand sense that only firms that are more efficient than their competitors can obtain positive profits; in particular, condition (1) is satisfied. Table 3 describes the long-term payoffs.

Table 3: **Intense Competition Example**

	T	NT
T	$1 - 2w^2 - I, -I$	$1 - w^1 - I, 0$
NT	$0, 1 - w^1 - I$	$0, 0$

To understand the table, note that, if both firms have trained, the only way to obtain a positive gross profit of 1 is to poach the other firm's worker. As a result, the equilibria of this subgame must be asymmetric. One firm employs both workers and has to pay wages that are so high that the workers are not poached by the competitor. Conversely, wages must be so low that the firm employing the two workers is not worse off than the competitor. Together, these two requirements imply  $1 - 2w^2 - I = -I$ . Hence, wages must be  $w^2 = 0.5$ . As neither firm can cover its training costs, this cannot be an equilibrium. Firms can always obtain zero long-term payoffs by refraining from training. This illustrates how intense competition works against training.

An asymmetric equilibrium with only one firm training cannot exist either: If only one firm has trained, both firms value the worker at 1. Hence,

$w^1 = 1$ , so that net profits of the firm who trained the worker are 0, and the long-term profits are negative whenever training costs are positive.

### 3.3 Summary

The examples suggest several conclusions. First, training additional workers can lead to a fall in wages. Second, when competition is sufficiently soft, a training equilibrium may exist. While these examples illustrate the potential role of the intensity of competition, the ad-hoc payoff structure and the restriction to one trained worker per firm are unsatisfactory. In the following, we shall therefore show that the intuition is nevertheless not misleading.

## 4 Analyzing the General Model

We now return to the more general model of Section 2 where firms can train arbitrary numbers of workers, and where product market profits result from more general kinds of oligopolistic interaction. We first show that under an assumption of “Decreasing Returns to Attracting Workers” each firm will end up with the same number of workers in the wage-bidding game, up to integer constraints. We shall then use this result to state conditions under which equilibria with and without training exist. Finally, we shall give a detailed interpretation of these conditions.

### 4.1 The Wage-Bidding Game

We first state conditions under which the wage-bidding game will lead to an even distribution of educated workers across firms, given that  $G$  workers have been trained in period 1. The following definition will be crucial.

**Definition 2** *If  $v(n^i, G)$  is decreasing in  $n^i$ , we shall say that there are Decreasing Returns to Attracting Workers (DRAW).*

In the Soft Competition Example of Section 2, condition (DRAW) holds: If both firms have trained, having one worker rather than none is worth 0.6 units, whereas poaching the second worker is worth only 0.2 units. In the Intense Competition Example, (DRAW) is violated, because if both firms have trained, only firms that employ both workers have positive profits.

Intuitively,  $v(n^i, G)$  reflects aspects of technology and product market competition. Technology determines how large the cost reduction is that arises from having an additional trained worker. Product market competition determines how this cost reduction (and the corresponding cost increase of the competitor) translates into higher profits.

The first main result contains two important conclusions. First, if (DRAW) holds, wage bidding will be such that workers are split equally across firms. Second, as argued intuitively in the examples in Section 3, wages correspond to the firms marginal valuation for attracting another trained worker.

**Proposition 1** *Suppose that assumptions 1- 2 and (DRAW) hold.*

(A) *Then the wage-bidding game has an equilibrium such that, up to integer constraints, both firms employ the same number  $N$  of trained workers.*<sup>16</sup>

(B) *In this equilibrium, each educated worker obtains wage offers*

$$w^*(N, G) = v(N, G).$$

(C) *There is no equilibrium with  $|n^j - n^i| > 1$ .*

**Proof.** See Appendix.<sup>17</sup> ■

The intuition for this result is as follows: If (DRAW) holds and workers are distributed evenly, each firm values an additional worker less than the competitor values keeping this worker. With an uneven distribution, the firm with the smaller number of workers is willing to pay more for at least one of

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<sup>16</sup>When an uneven number of  $2N + 1$  workers have been trained, one firm trains  $N$  workers, whereas the other firm trains  $N + 1$ .

<sup>17</sup>The result in the appendix uses a slightly weaker requirement than (DRAW) which is useful for the product differentiation example in section 4.3.



the competitor's worker than he is prepared to pay for keeping him. Thus, equilibria must result in an even distribution of workers. Wages correspond to the value of an additional worker,  $v(N, G)$ .<sup>18,19</sup> Consistent with the examples of Section 3, wages are therefore highest when it pays a lot to escape neck-to-neck competition, that is, competition is intense.

## 4.2 Subgame Perfect Equilibrium

We now analyze the subgame perfect equilibrium of the entire game.

Doing this for a discrete number of workers is tedious, as it requires distinguishing between even and odd numbers. We use a continuous approximation instead, building from the two main insights of the wage-bidding game analyzed in section 4.1, which, to repeat, are as follows. First, if assumption (DRAW) holds,  $n^i = n^j = G/2$ , up to integer constraints. Second, the equilibrium wage equals the productivity of the marginal worker,  $v(n^i, G)$ . Recall that this term contains both the positive effect for the firm from employing more workers itself and the effect that the competitor employs less workers. Therefore, a natural extension to the continuous case is to define  $v(n^i, G) \equiv \frac{\partial \pi}{\partial n^i} - \frac{\partial \pi}{\partial n^j}$  (evaluated at  $(n^i, G - n^i)$ ) and to equate the equilibrium wage with  $v(n^i, G)$ , that is, the marginal value of poaching an employee for firm  $i$ , which consists of the effect of employing more workers oneself  $\left(\frac{\partial \pi}{\partial n^i}\right)$  and of reducing the number of workers employed by the competitor  $\left(-\frac{\partial \pi}{\partial n^j}\right)$ .

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<sup>18</sup>The same equilibrium obtains in a competitive labor market framework when firms take wages and demand for trained workers of other firms as given. Therefore, equilibria with training can occur in a competitive labor market with demand externalities. Details are available from the authors upon request.

<sup>19</sup>It is straightforward to show that any other wage profile where everybody is offered the same wage between  $v(N - 1, G)$  and  $v(N, G)$  is also an equilibrium with an even distribution of workers. However, these other equilibria are Pareto-inefficient from the firms' point of view, since wage costs are higher than in the equilibrium described in Proposition 1. In the following, we assume that the firms achieve an equilibrium distribution of workers at minimal wage costs, i.e., we use the Pareto criterion among firms as a selection device. Since firms make wage offers, this assumption is plausible.

Using these two results from the discrete game to approximate the second period equilibrium in the continuous game, we immediately obtain

**Lemma 1** *Suppose (DRAW) holds. If firms choose training levels  $g^i$  and  $g^j$  and the second-period training equilibrium is played, firm  $i$ 's long-term payoffs in the continuous approximation of the game are*

$$\Pi(g^i, g^j) = \pi\left(\frac{G}{2}, \frac{G}{2}\right) - \frac{G}{2} \left[ v\left(\frac{G}{2}, G\right) \right] - g^i \cdot I.$$

This result implies a simple condition for an equilibrium without training.

**Proposition 2** *Suppose that (DRAW) holds. An equilibrium without training exists if and only if*

$$\pi(g, g) - g \cdot [v(g, 2g)] - \pi(0, 0) - 2gI \leq 0 \text{ for all } g \geq 0. \quad (2)$$

**Proof.** Consider firm 1. By Lemma 1, deviating from  $(0, 0)$  to  $g^1 > 0$  gives a profit of  $\pi\left(\frac{g^1}{2}, \frac{g^1}{2}\right) - \frac{g^1}{2} \left[ v\left(\frac{g^1}{2}, g^1\right) \right] - g^1 \cdot I$  as compared to  $\pi(0, 0)$  in equilibrium. With  $g = \frac{g^1}{2}$ , the statement follows. ■

For sufficiently low investment costs, (2) will hold for any level of training costs if competition is intense. For intense competition, therefore, there always is a no-training equilibrium.

Next, we give a condition under which there is an equilibrium with training, but no equilibrium without training.

**Proposition 3** *Suppose that (DRAW) holds and (2) is violated. Any equilibrium involves training and an equilibrium with training exists.*

**Proof.** Clearly, by Proposition 2, if (2) is violated, there can be no equilibrium without training. Both players' payoff functions are continuous. Because product market profits are bounded above and training costs increase above all bounds as  $g^i$  increases, by eliminating dominated strategies, one can assume w.l.o.g. that strategy spaces are compact. Thus, the game has a

pure-strategy equilibrium. By Proposition 2, this equilibrium must involve training. ■

In particular, there always is a training equilibrium under soft competition when (DRAW) holds and investment costs are sufficiently low. The proposition does not necessarily imply that both firms provide training. Necessary conditions for a symmetric equilibrium where both firms train are the following.

**Proposition 4** *Suppose (DRAW) holds. A training equilibrium with  $g^i = g^*$  requires:*

$$\pi(g^*, g^*) - \pi\left(\frac{g^*}{2}, \frac{g^*}{2}\right) \geq g^* \cdot [v(g^*, 2g^*)] - \frac{g^*}{2} \cdot \left[v\left(\frac{g^*}{2}, g^*\right)\right] + g^* I \quad (3)$$

and

$$\frac{\partial \pi}{\partial n^j} - \frac{g^*}{2} \cdot \left(\frac{\partial^2 \pi}{(\partial n^i)^2} - \frac{\partial^2 \pi}{(\partial n^j)^2}\right) = I, \quad (4)$$

where all derivatives are evaluated at  $(n^i, n^j) = (g^*, g^*)$ .

The first condition merely states that deviating to no training is not profitable. The second condition follows immediately from lemma 1, which yields the first-order condition

$$\frac{\partial \Pi}{\partial g^i} = \frac{1}{2} \frac{\partial \pi}{\partial n^i} + \frac{1}{2} \frac{\partial \pi}{\partial n^j} - \frac{1}{2} \left(\frac{\partial \pi}{\partial n^i} - \frac{\partial \pi}{\partial n^j}\right) - \frac{g^*}{2} \left(\frac{\partial^2 \pi}{(\partial n^i)^2} - \frac{\partial^2 \pi}{(\partial n^j)^2}\right) - I = 0, \quad (5)$$

where all derivatives are evaluated at  $(n^i, n^j) = (g^*, g^*)$ . Rearranging (5) leads to the second condition.

To understand (5), note that the total effect of an additional marginal trained worker on gross profits thus has the following four components.

1. (OPE) The *own productivity effect* ( $\frac{1}{2} \frac{\partial \pi}{\partial n^i} > 0$ ): As workers are distributed equally in the equilibrium of the wage-bidding game, only half of the marginal increase in the number of trained workers becomes effective in increasing gross profits for firm  $i$  under consideration.

2. (CPE) The *competitor productivity effect* ( $\frac{1}{2} \frac{\partial \pi}{\partial n^j} < 0$ ): The second half of the increase in trained labor will end up with the competitor, leading to a negative effect on one's own gross product market profit.
3. (ATW) Wages for *additional trained workers* ( $-\frac{1}{2} \left( \frac{\partial \pi}{\partial n^i} - \frac{\partial \pi}{\partial n^j} \right) < 0$ ): As half of the additional trained labor is employed by the firm under consideration, this results in additional wage payments of half the wage rate.
4. (WTW) Changes in *wages per trained worker* ( $-\frac{g^*}{2} \cdot \left( \frac{\partial^2 \pi}{(\partial n^i)^2} - \frac{\partial^2 \pi}{(\partial n^j)^2} \right)$ ): The sign of WTW is not fully specified by our assumptions. However, the intuition that additional competition among trained workers drives down wages typically holds if Condition (DRAW) is satisfied. Appendix 2 contains a technical discussion of the sign of the wage effect.

The total effect of OPE, CPE and ATW is  $\frac{\partial \pi}{\partial n^j} < 0$  for marginal changes. Thus, increasing the number of workers in the market marginally is only worthwhile if the negative effect (CPE) is outweighed by a sufficient reduction in wages for inframarginal workers (WTW).

Several comments on the training equilibrium are worth making.

First, it is immediately clear that an equilibrium with positive amounts of training requires that for suitable levels of  $(g^i, g^j)$ , a marginal increase in own training has a positive effect on long-term payoffs for player  $i$ . In particular, the increase in gross profits from training (including the negative effect on competitors) must be at least as large as the increase in wage costs. This condition is known as the requirement of a *compressed wage structure* in models of general training (e.g., Acemoglu and Pischke 1999).

Second, the equal distribution of workers implied by (DRAW) is crucial for training to exist in equilibrium. Suppose that, as an extreme counterexample, one of the firms attracts all trained workers. Then, there can be no training: Both firms will have the same net product market profits, which amount to the gross profits of the firm without trained workers.<sup>20</sup> These

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<sup>20</sup>If the firm that has no trained workers has lower net profits, it can imitate the firm

profits are smaller than gross profits if neither firm trains. Therefore, in such cases the training equilibrium cannot exist. Note that condition (DRAW) implies for a symmetric situation that there is no turnover. This links our paper to familiar results from the literature suggesting that there is a negative relation between training and expected turnover.

Third, while Proposition 3 gives conditions where only equilibria with training exist, equilibria with and without training may also exist simultaneously. Using Propositions 2 and 4, this would require that conditions (2) and (3) hold simultaneously.

Finally, even though we do not explicitly treat the case of more than two firms, intuition suggests that, for given market size, training is less likely to arise in equilibrium for large numbers of firms. As argued above, such an equilibrium necessarily requires a sufficiently large effect of own training on wages. When there are many firms, however, the own effect on wages is likely to be small. Thus, again, it appears likely that increasing product market competition decreases training incentives.

### 4.3 Examples

In the following, we consider several examples, strengthening the claim that training can arise only if product-market competition is sufficiently soft. In our working paper (Gersbach and Schmutzler 2003), we give examples for Cournot competition; here, we focus on price competition.

#### 4.3.1 Price Competition with Homogeneous Firms

The first example is a general reformulation of the point from Section 3 that training cannot arise for intense competition. To this end, consider two firms who can potentially train arbitrarily many workers. Suppose they compete à la Bertrand, that is, they sell homogeneous goods and choose

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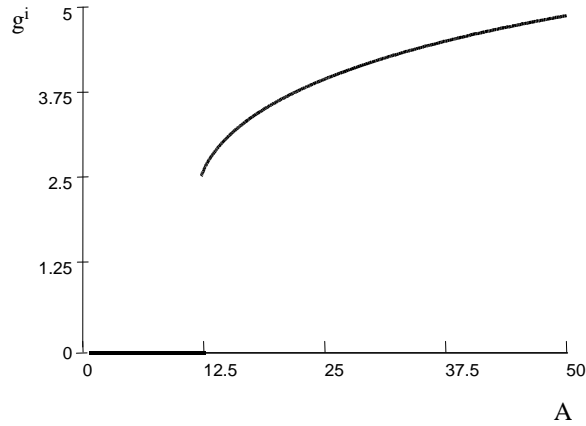
that employs the workers by making slightly more attractive wage offers to all of the workers than the competitor.

prices simultaneously. Suppose that marginal costs are a decreasing function of the number of trained workers employed in a firm.

Then, as in the intense-competition example in Section 3, if some workers have been trained, there must be an asymmetric equilibrium of the wage-bidding game in which both firms obtain the same net profit, namely zero. Thus, long-term payoffs would be negative in any equilibrium with training, and hence no training is the only equilibrium.

### 4.3.2 Price Competition with Heterogeneous Firms

As a numerical example, we consider the case of price competition of two firms producing imperfect substitutes, with demand functions  $D_i(p_i, p_j) = A - 10p_i + p_j$ , where  $0 \leq A \leq 30$ . We specify the training technology as  $c_i = 2 \exp(-n_i)$ . Thus, marginal costs are  $c_i = 2$  without training, and they decrease exponentially with training. For simplicity, we suppose that each firm is restricted to training at most  $g^i = 4.15$  workers. Using the logic of Proposition 1, this assumption can be shown to guarantee that workers are distributed equally in the wage-bidding game. Finally, we set  $I = 0$  to investigate under which circumstances a training equilibrium would exist for sufficiently low training costs. Figure 3 plots equilibrium training levels as a function of the market size parameter. The outcome is in line with our general intuition: For low parameter values, no training takes place. Around  $A = 12.1$ , a second equilibrium emerges, with training level  $g^i \approx 2.45$ . As  $A$  increases further, training increases further.



Equilibrium Training Levels

Thus, as greater market size corresponds to softer competition, we obtain another illustration of the idea that softer competition makes training more likely. In terms of economic intuition, there are two reasons why this is so. First, increasing market size increases the benefits from cost reductions – a standard scale effect which is familiar from the analysis of cost-reducing innovations. Second, for a given number of trained workers an increasing market size will raise the wages for such workers. By training more workers, this wage effect is alleviated.<sup>21</sup>

#### 4.4 Empirical Implications

All told, the analysis in this section clearly suggests that soft product market competition is favorable to training, because the costs of preventing turnover are relatively low. Testing this claim empirically is hard, in particular, because finding adequate measures of the intensity of product-market competition that are suitable for empirical analysis is difficult. Measures such as the Herfindahl index are inadequate because of their endogeneity: High

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<sup>21</sup>Whether equilibrium wages increase or decrease when market size expands depends on parameters.

concentration, which is often equated with soft competition, may well be the result of underlying competitiveness of the market environment (Sutton 1991, Boone 2007). Existing empirical evidence is nevertheless supportive of the mechanisms identified here. For instance, several authors have observed that training tends to be lower in regions where the density of economic activities is high (Mühlemann and Wolter 2006, Brunello and Gambarotto 2007). This evidence fits well with our theoretical results. In agglomerations, firms are more prone to poaching, because competition is intense. Starting from a training equilibrium, they would therefore have to offer high wages to prevent turnover. Similarly, the observation that large firms train more than small firms (Wolter et al. 2006, Bassanini et al. 2007) is consistent with our ideas. Large firms have to fear poaching less than small firms.

Clearly, however, a more direct test of the relation between product market competition and training would be desirable. An ideal design would use a natural experiment that can be interpreted as an increase in competition for some sets of firms in an economy, but not for others, and analyze the differential impact of this event on training.<sup>22</sup>

## 5 Welfare Results and Policy Discussion

Our analysis is partly motivated by different institutional arrangements in labor markets across the OECD. In some countries, such as Germany, firms offer apprenticeships to their workers. The knowledge acquired in such programs is mostly general in the sense of being applicable in other firms of the same industry. Nevertheless, firms bear part of the training costs. In contrast, the U.S. economy appears to generate less training that is non-specific to the firm than Germany or Japan, at least at the initial stage of a worker's

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<sup>22</sup>A possible candidate would be the revision of the Swiss cartel law which has been used successfully to identify the effects of increasing competition on exits (Bühler et al. 2005), using the fact that the effect of this law on exporting firms was negligible, because they were exposed to fierce competition even before.



life (Blinder and Kruger 1996, Acemoglu and Pischke 1998).<sup>23</sup>

For simplicity, we suppose that for each industry under consideration, the German and the U.S. labor and product markets are completely separated. Each of the two corresponds to one set of parameters of the game. In terms of our model, there are thus two different types of explanations of the apparent differences between Germany and the U.S. First, obviously, the relevant parameters of the game could differ across countries. Roughly speaking, Germany could be in a regime where a training equilibrium exists by Proposition 3, and the U.S. in a regime where it does not. The differences might come from industry characteristics such as the intensity of competition. Alternatively, state interventions might have affected the payoff functions. Second, one could think of the game as being the same in both countries, with both countries in different equilibria. German firms have coordinated on the training equilibrium, while US firms are in the no-training equilibrium.

Regarding welfare, we have already seen in the soft competition example of Section 2 that in the presence of multiple equilibria firms may be worse off in the training equilibrium than in the no-training equilibrium. As trained workers and consumers are better off when firms invest in training, training in the presence of multiple equilibria is socially desirable if (1) firms benefit from training or (2) consumers and workers have a sufficiently large weight in the social welfare function when firms prefer no training.<sup>24</sup>

In the former case, no government intervention is necessary if firms coordinate on the payoff-dominant equilibrium. In the latter case, if firms coordinate on the no-training equilibrium, there could be a role for government to induce training. First, government intervention could bring industries into the training equilibrium. On the one hand, the state can offer complementary investments such as schooling facilities where costless classroom education is provided. On the other hand, temporary support for general training invest-

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<sup>23</sup>Training investment in later stages of a worker's life is relatively low in Germany (OECD 1999), but the differences in the initial stage appear to be more substantial.

<sup>24</sup>In all the examples we have investigated, training is socially desirable when the social welfare function is the unweighted sum of producer surplus, wages and consumer surplus.

ment may establish a social norm which will remain after direct support has been withdrawn. Apart from granting direct financial aid, governments could provide such temporary support by promoting universal acceptance of certificates from apprenticeships. Which coordination mechanisms might be at work in Germany or in other countries is beyond the scope of this paper, but the preceding considerations raise the question of whether complementary activities or temporary support of the state could be useful to lead firms into the training equilibrium.

Perhaps the most important implication of our model is that increasing competitive intensity might destroy the training equilibrium. This suggests a crucial question: Can apprenticeships survive as firms are becoming more and more exposed to competitors from countries without such programs?

## 6 Conclusions

In this paper, we provide a theory of industry-specific training. Our explanation of training does not rely on asymmetric information in the labor market. Instead, we require imperfect product market competition to generate equilibria with general training in a world where turnover is endogenous.

Training equilibria exist for plausible parameter values, possibly together with the no-training equilibrium. We do not claim that training is likely in all industries. The most important conditions concern the training technology and the intensity of product market competition. Competition must be sufficiently soft and returns to training must decrease sufficiently fast for turnover to be avoided and training to arise in equilibrium. Otherwise firms would have strong incentives to escape neck-to-neck competition by hiring the competitor's worker.

The arguments have been cast in a duopoly framework. They appear to hold more widely in an oligopolistic framework, but it is important to investigate how the number of firms in a market affects the likelihood of a training equilibrium. As discussed in Section 4.2, a plausible conjecture is

that training becomes less likely as the number of firms increases, because competition becomes more intense. Indeed this is true in the Cournot case with linear demand.<sup>25</sup>

## 7 Appendices

### 7.1 Appendix 1: Proof of Proposition 1

**Proof.** For existence, we restrict ourselves to the case where  $G = 2N$  is even; the case  $G = 2N + 1$  is similar. We first show that, given the competitor's wage offers  $w^*(N, G)$ , lowering wages is not profitable. Suppose the firm reduces its wage offer to  $k$  workers ( $k \leq N$ ) so that it ends up with only  $N - k$  workers. This deviation is not profitable if

$$\pi(N, N) - k \cdot w^*(N, G) \geq \pi(N - k, N + k).$$

As  $w^*(N, G) = \pi(N + 1, N - 1) - \pi(N, N)$ , this is equivalent to:

$$\pi(N, N) - \pi(N - k, N + k) \geq k(\pi(N + 1, N - 1) - \pi(N, N)),$$

which is implied by (DRAW). Thus, downward deviation is not profitable. As to upward deviations, a higher wage offer for one worker would yield an increase in gross profits of  $\pi(N + 1, N - 1) - \pi(N, N)$ , which is exactly offset by the additional wage payments  $w^*(N, G)$ . By (DRAW), attracting any further worker would yield additional gross profits smaller than  $\pi(N + 1, N - 1) - \pi(N, N)$  and thus smaller than the additional wage payment. Hence, there are no profitable deviations.

To show that there is no equilibrium with  $n^i < n^j - 1$ , note that the willingness of firm  $i$  to pay for an additional worker is  $\pi(n^i + 1, G - n^i - 1) - \pi(n^i, G - n^i)$ , which by (DRAW) is greater than  $\pi(n^j, G - n^j) - \pi(n^j - 1, G - n^j + 1)$ , which is the value of the last worker that firm  $j$  employs ■

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<sup>25</sup>Details about such comparative exercises where the number of firms increases with and without adjustments of the market size are available upon request from the authors.

## 7.2 Appendix 2: The Wage Effect

**Proof.** We now argue that increasing training levels tend to reduce the wage level, i.e.,  $\frac{\partial^2 \pi}{(\partial n^i)^2} - \frac{\partial^2 \pi}{(\partial n^j)^2} < 0$ . Clearly, this is true if  $\pi$  is concave as a function of  $n^i$  and convex as a function of  $n^j$ . Also, condition (DRAW), i.e., concavity of  $\pi(n, G - n)$  as a function of  $n$  implies that  $\frac{\partial^2 \pi}{(\partial n^i)^2} + \frac{\partial^2 \pi}{(\partial n^j)^2} - 2\frac{\partial^2 \pi}{\partial n^i \partial n^j} < 0$ . Unless  $\frac{\partial^2 \pi}{\partial n^i \partial n^j} - \frac{\partial^2 \pi}{(\partial n^j)^2}$  is very positive, therefore,<sup>26</sup>

$$\frac{\partial^2 \pi}{(\partial n^i)^2} - \frac{\partial^2 \pi}{(\partial n^j)^2} = \frac{\partial^2 \pi}{(\partial n^i)^2} + \frac{\partial^2 \pi}{(\partial n^j)^2} - 2\frac{\partial^2 \pi}{\partial n^i \partial n^j} + 2\left(\frac{\partial^2 \pi}{\partial n^i \partial n^j} - \frac{\partial^2 \pi}{(\partial n^j)^2}\right) < 0$$

and (WPTW) is therefore positive. ■

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<sup>26</sup>This is not likely: Typically, at least  $\frac{\partial^2 \pi^i}{\partial n^i \partial n^j} < 0$ , roughly speaking, because the positive effect of trained workers on the own mark-up of a firm is higher when the other firm has less trained workers and thus faces a smaller market share.

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