THE ECONOMICS OF PRIVATE SECTOR TRAINING: A SURVEY OF THE LITERATURE

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Abstract. This survey organizes and summarizes existing theoretical work on private sector training. The theoretical models focus on investment efficiency, finance and turnover. Recent developments in the on-the-job training literature are characterized by strategic interaction between employers and employees and emphasize market imperfections.

Keywords. Human capital; Investment; Training

1. Introduction

This paper provides a survey of the economic literature on private sector training. It therefore considers on-the-job training and does not discuss formal education or training of the unemployed or any learning activities that workers undertake independently from their employer. This of course does not imply that insights from the on-the-job training literature are not relevant for other types of training and education.

Human capital theory as formalized by Becker (1962) is the dominant perspective on on-the-job training. This theory views training as an investment; it raises expected future productivity but at a cost. The key distinguishing feature of a human capital investment as opposed to an investment in capital concerns property rights. A machine can be sold, but in modern society, men cannot. As individuals have the discretion over the deployment of their own human capital, workers and firms will need to agree on an exchange in the labour market. This implies that how the costs and returns to training are shared between workers and firms is a central concern in the on-the-job training literature.

Human capital theory has been further developed in the 1970s to explain the life-cycle pattern of earnings. This literature analyses the human capital investment decision of individuals in a competitive environment. One may argue that, in this model, the distinction between education and training is an artificial one. Workers choose the investment as a function of prices (and ability). Through

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these prices, the demand side enters. There is no strategic interaction between workers and firms. Weiss (1986) surveys this literature.

In the beginning of the 1990s, the new field of economics of information resulted in applications to on-the-job training. We will see that these recent developments in the training literature focus on the strategic interaction between employers and employees, and as such stands apart from life-cycle theories of earnings. The focus is on market imperfections and information asymmetries. This review restricts itself to the core of private sector training theory. The reason for this focus is the scattered nature of this literature. The studies in this field differ in many modelling assumptions that complicate comparison. Yet, some common themes can be distinguished. The main concerns of the theoretical economic literature on training are the following:

- Investment efficiency,
- Separation efficiency,
- Division of costs and returns.

The review will therefore present the results in these terms and highlight additional insights where necessary.

The outline of this paper is as follows. The next section presents an overview of models of training. Section 3 presents the standard model of general training. After which specific training will be discussed in section 4. Section 5 considers the impact of contract (re)negotiations on investment incentives and hold-up, after which section 6 discusses market imperfections and specific sources thereof in more depth. Section 7 offers a brief summary of the main insights and discusses implications for policy and further research.

2. Models of Training

Becker (1962) is the first reference for anyone interested in the economics of training.[1] In this seminal paper, a simple two-period model is presented. Becker assumes that labour and product markets are perfectly competitive and distinguishes two types of training: general training and specific training (definitions are given in the next section). The analysis of Becker has subsequently been extended and refined by other authors to take imperfect competition and the role of information asymmetries into account. In many respects, these models still resemble Becker's analysis. The distinction of general and specific is still important, and most models in this literature are two-period models.

Figure 1 gives a description of the timing of events in the prototypical model of on-the-job training. There is a training period and a production period, and each of them can be preceded by contract negotiations (wages are set and training can be contractible). Most models are of a non-cooperative nature, and other modelling assumptions vary more widely. Some models assume free entry at the first stage, thereby imposing a zero profit condition on the firm and creating a cooperative outcome. Models also vary in the extent to which they allow ex-ante uncertainty, thereby justifying the renegotiation of the initial contract

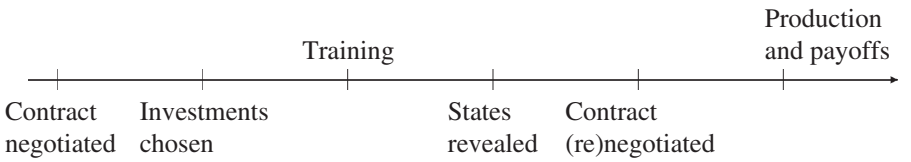

Figure 1. Timing of Events in Prototypical Models of Training.

after the arrival of new information. Finally, the different analyses vary in the assumptions they make about the observability of training and/or ability, and who has this information and when.

Contract negotiations typically take the form in which the firm proposes an initial contract (possibly in the presence of competition or strategic bidding of outside firms). The worker may then accept the contract or take-up his market alternative. On accepting, the worker is automatically trained if the contract specifies a training level, otherwise the firm or the worker may decide to invest. After training, ex-ante uncertain information may become known to one or more parties. Examples of sources of uncertainty are the worker's ability, an outside option or the value of the match. Then, before entering second period employment, there may be, again, a contracting phase in which the second period wage is (re)negotiated and the worker may separate from the training firm. After this, production takes place and the parties retire.

It will be convenient to introduce some notation at this point. Throughout the paper we will use s to denote training. Training s can be continuous or dichotomous depending on the specific model under consideration. Cost of training is $c(s)$. Output in period t in the training firm given training s is denoted by $y_t(s)$ and similarly market productivity in period t equals $\overline{y}_t(s)$. Finally, period t wages are written as $w_t(s)$ and market wages are $\overline{w}_t(s)$. Table 1 provides an overview of the notation.

The following assumptions are made:

Assumption 1.1. Firms maximize expected profits and workers maximize expected lifetime earnings.

Insurance motives are typically ignored:

Table 1. Overview of Notation.

Quantity	Description
s	Amount of training (time),
$y_t(s)$	Period productivity in training firm, (t=1,2)
$\overline{y}_t(s)$	Period productivity in alternative employment, (t=1,2)
$w_t(s)$	Period wage in training firm, (t=1,2)
$\overline{w}_t(s)$	Period wage in alternative employment, (t=1,2)
$c(s)$	Training cost

Assumption 1.2. Firms and workers are risk neutral.

There is no discounting. In addition, to avoid corner solutions, the following (standard) regularity assumptions are made to ensure the existence of a positive training level in equilibrium:

Assumption 1.3. $c(s)$ *is increasing and strictly convex in* s. *In addition,* $c(0) = 0$, $\lim_{s\to 0} c'(s) = 0$ *and* $\lim_{s\to\infty} c'(s) = \infty$
and

Assumption 1.4. $y_2(s)$, $\overline{y}_2(s)$ *are non-decreasing and concave in* s.

It is also assumed that training (as compared with no training) is socially optimal.

These are the most important assumptions. They will be augmented with other assumptions where necessary. The next section starts with the standard model of training where it is assumed that markets are perfectly competitive.

3. Perfect Competition

The standard model of training is a model of full competition where training is general. Becker (1962) defined general training as training that it is equally useful in many firms:

Definition 1. *Training is general if* $\overline{y}_2(s) = y_2(s)$.

Becker argued that if training is general and labour (and product) markets are perfectly competitive, then firms will not be prepared to finance this training. Workers will reap all the returns and will therefore bear all the training costs. The basic argument runs as follows. With competitive labour markets, workers can receive a market wage that is equal to the value of their marginal product in the market. As training is general, the value of their marginal productivity is the same in the training firm and the market, the training firm will be obliged to pay workers their full marginal productivity. Because the firm does not reap any of the benefits, it will not be prepared to finance general training. If it would, the worker could leave after training and capture the full returns without reimbursing the cost of training to the firm (in the absence of a contract specifying a breach remedy). Becker showed that workers may pay for the general training they receive through lower wages during the training period.

The structure of Becker's model is shown in Figure 2. A firm offers training amount s and starting wage w_1. The worker accepts (A) or rejects ($\sim A$). If the worker rejects, he enters the market and receives the wage of an unskilled worker. If the worker accepts, he is trained. After training, the firm offers a second-period wage. The worker quits (Q) if the firm's wage offer is less than what the worker can earn in the market and stays ($\sim Q$) otherwise. In the second period, production takes place after which the parties receive their payoffs and retire.

In addition to definition 1, it is also assumed that there is perfect competition in the labour market. This can be modelled by assuming that there is free entry. As a result, Bertrand competition at the start of the second period will drive the market wage $\overline{w}_2$ to the value of worker productivity $\overline{y}_2$.[2] The training firm is

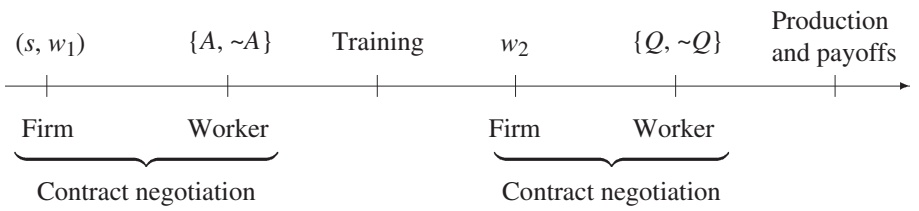

Figure 2. Timing in the Standard Competitive Model of General Training.

therefore obliged to offer at least the market wage $\overline{w}_2$ because the worker will quit otherwise. However, as training is general, it follows that the training firm will offer exactly $w_2 = \overline{w}_2 = y_2$; the worker is paid his marginal product. Similarly, free entry in the first stage, where firms will compete to attract workers, results in zero profits and will drive down the first-period wage to $w_1 = y_1 - c$; workers pay for training through lower starting wages.

Finally, note that investment is also efficient. As the worker receives $w_1 + w_2 = y_1 - c(s) + w_2(s)$, he is prepared to pay for investment up to the level s that solves the first-order condition $w'_2(s) = c'(s)$. As the labour market is competitive ($w_2 = y_2$), this is identical to $y'_2(s^*) = c'(s^*)$, the first order condition for socially efficient investment s^*.

The firm will offer exactly s^* of training. Offering more will result in a lower profit, and the firm will be driven out of the market by new entrants. If the firm offers less, other firms have an incentive to offer slightly more training. This will drive the equilibrium investment level to s^*. This proves the following proposition:

Proposition 1. *If training is general and labour markets are perfectly competitive then*

(i) The worker will be the full residual claimant and receive all the returns and will also pay the full costs through lower wages.
(ii) Investment is efficient.

Proof. See text above or Becker (1962, 1993).

Moreover, in equilibrium, all workers are trained and all firms train.[3]

Pigou (1912) argued that under-investment in general training would occur, as firms in competitive labour markets have no incentive to provide training. This is the famous poaching externality: outside firms hire the trained workers away, thereby inflicting a capital loss on the training firms who, anticipating this, will not train their workers. Proposition 1 shows that although firms do not have an incentive to pay for general training, workers do. Moreover, workers can finance this training by taking a wage cut. As a consequence, the poaching externality disappears and there is no under-investment. The under-investment problem re-surfaces, however, if the worker is liquidity constrained. Minimum wages

may also give rise to under-investment, as these may prevent wages to fall to levels necessary to pay for training.[4]

4. Imperfect Competition

Not all training will be equally productive in all firms as is the case with general training. Clearly, training exists which will increase productivity by a different amount in the firm where training takes place compared with other firms. An example is the extreme case in which training is specific to the firm where training takes place.

Although not clear in his definition of general training, Becker (1962) recognized that, if training is technologically general, the degree of competition in the labour market determines whether it is general in an economic sense:

> In extreme types of monopsony [...] all training, no matter what its nature, would be specific. [...] The effect on training of less extreme monopsony positions is more difficult to assess. [...] But monopsony power as a whole, including the more extreme manifestations, would appear to increase the importance of specific training and the incentive for firms to invest in human capital (Becker, 1962, pp. 50–51).

Becker's (1962) analysis of general training rests on the assumption that labour markets are competitive. Yet, there are many reasons why labour markets are not competitive, examples are asymmetric information, institutions and search frictions. To illustrate how imperfect competition changes investment incentives, it is useful to start with the extreme case in which there is only one buyer for a particular type of skill: specific training.

Timing is again as in Figure 2, but now training is specific. Specific training can be defined as training that is only useful in the training firm and has no effect on the worker's productivity in other firms:

Definition 2. *Training is specific if* $\overline{y}_2(s) = y_2(0)$.

When training is specific, workers will not pay for this training (either through accepting lower wages or directly) but firms will. To see this, consider what happens if the firm refuses to pay the worker the value of his marginal product $y_2(s)$. In the case of general training, we saw above that the worker could just leave and receive his marginal product in the market $\overline{w}_2 = y_2(s)$, but this is no longer possible when training is specific. As labour markets are competitive, the outside wage that the worker can receive equals the value of his marginal productivity in the market $\overline{w}_2 = \overline{y}_2 = y_2(0)$. Assume that the firm makes a take-it-or-leave-it wage offer (the firm sets wages). There is no reason for the incumbent firm to offer more than the market wage and the worker will accept this wage.[5] The worker does not receive part of the returns on specific training and is therefore not prepared to finance (part of) this training. The firm on the other hand captures the full return to specific training, and as it also pays the full cost, investment is efficient. This gives us the following result.

Proposition 2. *If training is specific and the firm sets wages then*

(i) The firm will be the residual claimant and receive all the returns. It will also pay the costs.
(ii) Investment is efficient.

At this point, Becker introduced turnover in his argument. If the worker and the firm separate after training, the (specific) investment is effectively lost, as it is only of value within the match. Becker conjectured that the firm and the worker will share the return. By paying the worker a higher wage, the firm reduces (costly) turnover. Because there will now be an excess supply of trainees, workers will need to share part of the costs in order to re-establish equilibrium. This sharing argument is not made in a formal manner. Regarding the exact size of the share, Becker remarks that 'the shares of each depend on the relation between quit rates and wages, layoff rates and profits, and on other factors not discussed here, such as the cost of funds, attitudes toward risk, and desires for liquidity'. (p. 44)[6]

Hashimoto (1981) formalized Becker's conjecture in a model with transaction costs. The timing in this model is shown in Figure 3. At the start of period 1, the worker and the firm write a long-term contract specifying the investment level and wages in period 1 and 2. The worker and the firm are ex-ante uncertain about the outside opportunities $\overline{w}_2$ and the period 2 productivity of the worker y_2. At the start of the second period, the worker learns the value of his market alternative $\overline{w}_2$, the firm does not. The firm, however, learns the value of the worker's product y_2; yet, the worker does not.[7] The firm will now lay off the worker if $w_2 < y_2$, whereas the worker on his side will quit if $w_2 < \overline{w}_2$.[8] Note that the worker may quit inefficiently ($\overline{w}_2 > w_2$ but $y_2 > \overline{w}_2$) and the firm may lay off (L) inefficiently ($y_2 < w_2$ but $\overline{w}_2 < y_2$). In fact, as renegotiation is not possible, separation will typically be inefficient.

To solve the model, Hashimoto assumes that the worker and firm maximize joint surplus and w_2 is therefore set in such a way as to minimize the ex-ante expected (social) cost of this inefficient turnover by balancing the cost of inefficient quits vs. the cost of inefficient layoffs. Free entry at the start of period 1 makes that w_1 is set such as to drive expected profits to zero.

It is important to note that as, by definition, the investment has no externalities, investment is efficient, even if there is ex-postinefficient turnover. In general,

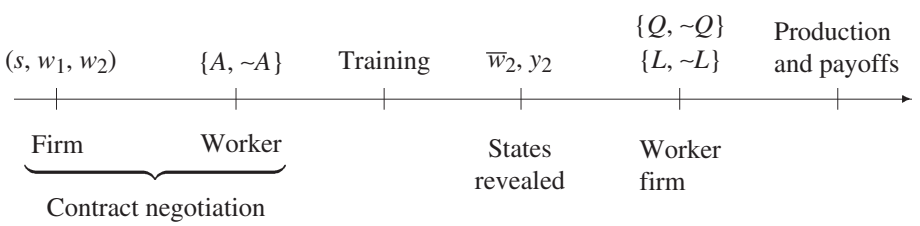

Figure 3. Timing of Events in Transaction Cost Model of Specific Training.

as the investment is specific, increasing the level of s will reduce the probability of a separation. Investment and turnover are therefore not independent. Solving the model gives the following result:

Proposition 3. *If training is specific, long-term contracting is possible (no renegotiation) and there are costs of evaluating and agreeing on the worker's productivities in the firm and elsewhere,*

(i) The returns will be shared between the worker and the firm and so will the costs.
(ii) Investment is efficient.

Proof. See Hashimoto (1981).

One might wonder whether the sharing results hold for other wage setting schemes. Leuven and Oosterbeek (2001) presented comparative statics results in the Hashimoto model both under the predetermined wage and the firm-sets-wage contract (see below). They also showed that the sharing argument is still valid under the latter contract.

Hashimoto's model has been influential, and subsequent research has extended it in various ways.[9] Carmicheal (1983), for example, showed that, if one allows that a worker is promoted with probability p during period 2 (based on a seniority rule where the number of senior jobs are fixed), wages can be set in such a way as to induce efficient turnover. To see this, suppose that the wage in the entry job is w_2 and in the senior job w_2+B. At the start of the second period, the firm will now fire the worker if $y_2 < w_2$ and the employee will quit if $\overline{w}_2 > w_2 + p \cdot B$. Because the number of senior jobs is fixed, another employee will get promoted if the employee under consideration is not. This means that the firm only saves w_2 with a lay-off and not $w_2 + B$. With this extra degree of freedom, w_2 will be set such as to induce ex-ante efficient lay-offs and B such as to induce ex-ante efficient quits (note that ex-post there are still inefficient separations in the absence of renegotiation).

Hall and Lazear (1984) investigated how other contracts than the long-term (predetermined) wage contract analysed above perform in terms of separation efficiency. In particular, they analyse unilateral wage setting contracts which they call firm-sets-wages and worker-sets-wage contracts. In the firm-sets-wages contract, the incumbent firm observes the worker's productivity y_2 and makes a wage offer w_2 which the worker can accept or reject. In the worker-sets-wage contract, the worker observes his market alternative and posts a wage demand w_2 at which the firm can hire the worker or not. Hall and Lazear (1984) showed that the firm always proposes a wage which is less than the worker's marginal product and, similarly, the worker always sets a wage above the value of his market alternative, even though this sometimes will result in an inefficient separation. This reflects that, in these unilateral wage-setting schemes, the wage-setting party acts as a monopolist. Which of the three contracts perform best in term of separation efficiency depends on the joint distribution of y_2 and $\bar{w}_2$. Full separation efficiency is, however, never obtained. This is implied by the analysis of Myerson and

Satterthwaite (1983) who have shown that, in the presence of two-sided asymmetric information, there does not exist an efficient trading mechanism. Hall and Lazear (1984) do not discuss investment efficiency.[10]

Hashimoto precluded renegotiation of the second-period wage because of excessive transaction costs. Malcomson (1997) argued that the firm-sets-wage contract is in fact a good description of the 'employment at will' practice in American labour markets and as such the above model can be a good approximation of real-world situations. However, one can imagine many relevant situations in which renegotiation will occur. The next sections consider the consequences of such renegotiation for training investment.

5. Hold-Up

Little attention has been paid so far to the effect of contract (re)negotiations on investments. There are, of course, many situations in which contracts are renegotiated after specific investments have been made. Renegotiation occurs because a contingent contract can not be written and because without renegotiation the parties will separate inefficiently.[11] In the renegotiation process, the non-investing party will often be able to capture part of the returns. As the investor no longer receives the full marginal return on his investment, he will under-invest. Williamson (1985) has coined this phenomenon 'hold-up' (Grout, 1984). Renegotiation therefore typically has adverse effects on investment incentives.

Renegotiation involves bargaining. In a bargaining situation, it is important to distinguish between the payoffs the parties get during bargaining and the payoffs they receive when bargaining breaks down and the parties take up other opportunities. The former type of payoffs are called default payoffs or threat points, and the latter type are called outside options. Bargaining can be explicitly modelled as an alternating offers game (Rubinstein, 1982). It has been shown that, when bargaining becomes frictionless, the equilibrium outcome in this game is equivalent to the Nash Bargaining Solution which tells us that bargaining will split the surplus (gains of trade relative to default payoffs) according to the parties' bargaining power, except if the outside options are binding (e.g. Binmore *et al*., 1986). Denote the worker's bargaining power by α, $\alpha \in [0,1]$. If $\alpha = 0$ then the firm has all bargaining power. This is equivalent to the firm-sets-wage contract in the previous section. If $\alpha = 1$, the worker has all bargaining power and this is equivalent to the worker-sets-wage contract.

To show that renegotiation typically has adverse effects on investment incentives suppose that, in the notation of this paper, an enforceable contract specifying a specific investment s cannot be written. Moreover, assume that it is the worker who invests and that the worker and the firm have the possibility to renegotiate the second-period wage. Efficient investment s^* equates marginal cost to marginal return: $c'(s^*) = y_2'(s^*)$.

If the default payoffs for both parties during bargaining are normalized to zero and outside options are not binding, then the worker's (renegotiated) second-period wage in the training firm will be equal to a share α of the surplus y_2:

$$w_2 = \alpha y_2$$

As $w_2 > \overline{w}_2$, the worker will not quit. To see what happens to the worker's investment, incentives in the case of renegotiation write down the worker's (indirect) utility function:

$$\begin{aligned} U &= w_2 - c(s) \\ &= \alpha y_2(s) - c(s) \end{aligned}$$

Inspection of the first-order condition, $c'(s^{**}) = \alpha y_2'(s^{**})$, shows that, if the worker does not have all bargaining power ($\alpha < 1$), the investment level in the presence of hold-up s^{**} is less than the efficient level s^*.

In this example, we assumed that outside options were not binding. When the firm's outside option ($\bar{\pi}$) is binding, we get a strikingly different result (still assuming that it is efficient for the parties to trade). The firm's outside option is binding if $\pi = y_2 - w_2 = (1 - \alpha)y_2 < \bar{\pi}$. From bargaining theory, we know that the wage will be renegotiated down to: $w_2 = y_2 - \bar{\pi}$ and now the worker chooses s to maximize:

$$\begin{aligned} U &= w_2 - c(s) \\ &= y_2(s) - \bar{\pi} - c(s) \end{aligned}$$

The first order condition is $c'(s) = y_2'(s)$, which shows that the worker will invest efficiently.[12]

We have seen that when contracts can be renegotiated workers may have insufficient incentives to collect firm-specific skills. If firms get a reputation for rewarding skill collection, the hold-up problem might be less severe or even non-existent (given that their discount rate is low enough). There is of course no guarantee that this is the case.[13] In a related paper, Leuven *et al.* (2004) showed that worker reciprocity can play a similar role as firm reputation in improving investment incentives for the other (investing) party.

5.1 *Contractual Solutions to Hold-Up*

Absence of reputation does not imply that workers and firms have no means to circumvent the hold-up problem. Sometimes it is possible to find a (contractual) solution for hold-up by employing compensation schemes for workers that are designed to induce them to collect non-verifiable firm-specific human capital. One example is the well-known up-or-out practice (Kahn and Huberman, 1988), and another example is a credible up-or-stay promotion rule (Prendergast, 1993). Both schemes depend on the assumption that, although firms cannot attach wages to skills, they can attach wages to tasks.[14]

First consider up-or-stay. There are two tasks, an easy (E) and a difficult (D) one. Instead of offering a uniform second-period wage w_2, the firm can now offer the worker a contract which specifies the wage for each task $\{w_E, w_D\}$. Assume for ease of exposition that training is indivisible $s \in \{0,1\}$. If the worker accepts the contract, he can either invest at cost c or not. Output in job D is denoted by $y_D(s)$ and $y_E(s)$ in job E. The production technology is such that within a job a trained

worker is more productive than an untrained worker. A trained worker is also assumed to be more productive in the difficult job, while an untrained worker is more productive in the easy job:

$$y_D(1) > y_E(1) > y_E(0) > y_D(0) \tag{1}$$

As usual, it is also assumed that training is efficient:

$$y_D(1) - y_E(0) > c \tag{2}$$

A worker will invest (i) if the wage increase on promotion is greater than the cost of investment:

$$w_D - w_E > c$$

and (ii) if the firm will promote him after training. The firm has an incentive to promote a trained worker if:

$$y_D(1) - y_E(1) > w_D - w_E$$

A contract that satisfies these two conditions solves the hold-up problem: the firm has an incentive to promote the worker, who then has an incentive to invest. The feasibility of the up-or-stay promotion rule depends on (i) whether firms can assign wages to tasks and (ii) whether the production technology allows credible assignment of workers to tasks. Note that the latter is not necessarily true, even if investment is efficient, as this requires that $y_D(1) - y_E(1) > c$ which is not implied by the efficiency condition (2).

If wages cannot (credibly) be assigned to different jobs which satisfy (1), the up-or-stay rule cannot be implemented. This will happen if the two jobs are just job titles with the same production technology or if they are quite similar. In this situation, the hold-up problem might be solved through an up-or-out rule (Kahn and Huberman, 1988). The idea here is that, after a fixed period of time, the firm either pays the worker a high wage w^* or fires him. For this to happen, w^* must satisfy the following condition $y_D(1) > w^* > y_E(0)$. The first inequality requires the worker to be productive enough in the difficult task, whereas the second inequality implies that an untrained worker is not productive enough in the easy task. The worker on his part will train if $> w^*; > c$. If investment is efficient, such a wage can always be found. As a consequence, all workers train and all workers are promoted.

If workers are heterogeneous, then the up-or-out rule performs not always that well. The reason for this is that if a worker can choose various levels of investment (training is no longer indivisible), some of the workers who invested, but not enough, will be fired and specific investments are lost. Moreover, if uncertainty is introduced, for example if training is not necessarily successful, then the investment efficiency of up-or-out typically comes at the cost of separation inefficiency.

6. Sources of Imperfect Competition

The previous sections reviewed human capital investment when there is only one buyer. This section shows that it is the degree of market competition for

a particular skill that determines whether training is, *de facto*, either general, specific, or somewhere in between.

Consider the case where there is more than 1 buyer, but competition is less than perfect. Training is assumed to be technologically general but, to illustrate the mechanism, assume that frictions (for the moment, of an undefined nature) lead to a market wage lower than the worker's productivity: $\overline{w}_2(s) < y_2(s)$. Moreover, suppose that the worker separates with exogenous probability q from the training firm, and that the firm invests in training. Assuming that the firm has all bargaining power, it will pay the worker his market alternative $w_2 = \overline{w}_2(s)$ and choose s such as to maximize its profits:

$$\pi = (1-q)(y_2(s) - \overline{w}_2(s)) - c(s)$$

The first-order condition is $(1-q)(y_2'(s) - \overline{w}_2(s)) = c'(s)$. For the firm to invest in training, the left-hand side of the first-order condition must be strictly greater than 0. This implies the following:

Proposition 4. *The firm invests in technologically general training if,*

(i) *There is a positive probability that the worker stays with the training firm:* $q < 1$.
(ii) *The marginal increase in a worker's productivity is not fully reflected in his best opportunity in the market:* $y_2'(s) > \overline{w}_2'(s)$.
(iii) *The firm makes a positive profit if it trains and employs the worker:* $y_2(s) - \overline{w}_2(s) - c(s) > 0$.[15]

Proof. See text or Acemoglu and Pischke (1999b).

Hence, if skill markets are non-competitive, firms may pay for technologically general training. This is a strikingly different result compared to the competitive model analysed above. The non-competitive model differs also in a second respect, highlighted by the following proposition.

Proposition 5. *Under imperfect competition, training investment is inefficient because of the poaching externality when*

(i) *The worker has a positive probability of leaving the training firm:* $q > 0$.
(ii) *It is profitable for the poaching firm to employ the trained worker:* $\overline{y}_2(s) - \overline{w}_2(s) > 0$.

Proof. See Stevens (1994b).

This is an important point. Becker argued that all training can be regarded as a sum of a general and a specific component. As a consequence, there is no positive externality and under-investment does not arise. The analysis of Stevens (1994b) shows that this is potentially misleading and that imperfect competition may cause training to have a transferable character, meaning that it is neither perfectly general nor perfectly specific, nor a convex combination of the two. If the market for skills is such that firms pay wages below marginal productivity and if there is uncertainty about labour turnover then

outside firms earn a positive expected profit on training. But these are externalities that are not internalized by the worker and the training firm when they decide on training, as they maximize their own joint surplus and not social surplus. Investment will therefore be inefficient, and the poaching externality reappears. Stevens does not discuss any specific market frictions, she notes that 'any source of imperfect competition leading to wages below marginal product, combined with any source of uncertainty about labour turnover, gives rise to this externality' (p. 541).

We have seen how imperfect competition generates different results compared to the competitive model without being explicit about the specific market frictions involved. The next subsections review, more in depth, specific sources of market imperfection.[16]

6.1 *Asymmetric Information*

Information asymmetries between the training firm and the market are such a mechanism. Two main cases can be distinguished. Firstly, the case where the training firm is better informed about the training of its employees than the market. Secondly, the case in which the training firm is better informed about the abilities of its workers giving rise to adverse selection.

6.1.1 *Training Not Observable by Outside Employers*

Katz and Ziderman (1990) forwarded the argument that, if incumbent firms have superior information about the training of their workers, then it might not be possible for those workers to capture the full return to technologically general training in the market. Potential recruiters, so they argued, are unlikely to know very much about the extent and type of training workers received with their current/previous employer(s). The result of this will be that a recruiting firm will place a lower (expected) value on a recruited worker with general training than the firm that trained him. The information asymmetry between the training firm and outside employers renders general training thus effectively specific.

Katz and Ziderman discussed the implications of this information asymmetry regarding liquidity constraints and certification. In the standard model of general training, if workers are liquidity constrained (either directly or indirectly when training can not be financed through wage cuts because of a binding minimum wage), they will not invest in general training. In the model of Katz and Ziderman, this under-investment problem is actually less severe, as employers will be prepared to participate in the cost of training.

Finally, certification may overcome the information asymmetry and thereby reduce firms' incentives to pay for general training. As a consequence, the under-investment problem will be aggravated by certification if workers are liquidity constrained.

Chang and Wang (1996) presented a formal model that borrows from Katz and Ziderman.[17] The timing of the model is shown in Figure 4. The first thing to note is that the first period wage w_1 is not made contingent on s. Chang and Wang

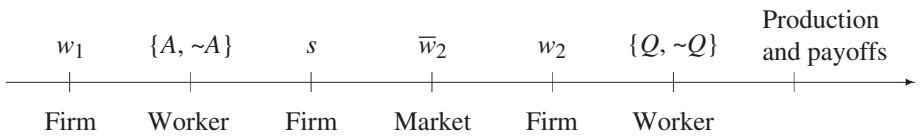

Figure 4. Timing of Events When Training Is Not Observed by Outside Employers.

(1996) made two other important assumptions: (i) they assume that $y_2 = s + \varepsilon$ and $\overline{y}_2 = \delta s + \eta$, which implies that in addition to a general investment δs there is a complementary specific investment $(1 - \delta)s$, and (ii) $w_2 = \overline{w}_2 + \alpha(y_2 - \overline{w}_2)$, the worker and firm share the surplus through Nash bargaining. Both ε and η are random job-match components.

Because outside firms do not observe the amount of training a worker received, they cannot base their wage offer $\overline{w}_2$ on s but only on the expected training level $E[s]$ (which equals the actual training level in equilibrium). As a consequence, the market wage is independent of the investment level that the firm chooses, and the firm has an incentive to pay (part) of the general component of training as long as there is a positive probability that the worker stays. The rational expectations equilibrium in the market is defined by

$$\overline{w}_2 = \delta E[s]$$

and $E[s] = s^*$, where s^* is the firms' optimal investment level. Note that the marginal increase of the worker's productivity is not fully reflected in his best market opportunity $\overline{w}'_2(s) = 0 < 1 = y'_2(s)$ as in condition (*ii*) of proposition 4.

The worker and the firm will separate if $y_2 < \overline{w}_2$; hence, the probability of separation is $q = \Pr(y_2 < \overline{w}_2)$. The firm's (second period) profit therefore becomes[18]

$$\pi = -w_1 + E[y_2 - w_2 | 1 - q] \cdot (1 - q) - c(s)$$

and, the firm maximizes profit subject to the worker's participation constraint,

$$w_1 + E[w_2 | 1 - q](1 - q) + \overline{w}_2 q \geq U$$

which is binding in the optimum. Substituting the binding participation constraint in the profit function it can be show that the first-order condition becomes

$$(1 - \alpha)(1 - q) = c'(s) \tag{3}$$

the optimal s^* solves (3). Like in Katz and Ziderman (1990) and as shown above, the most important result is that there is positive investment $s^* > 0$ if there is a positive probability that the worker stays with the firm and does not have all bargaining power q, $\alpha < 1$, which implies that the firm invests in general training. A number of additional results follow. First, note that the socially efficient level of investment s^e maximizes $\pi + (1 - q)w_2 + qE[\overline{y}_2]$ and therefore solves $1 - (1 - \delta)q = c'(s)$. Comparing this with (3) shows that there are two sources of under-investment. Firstly, the firm under-invests because of hold-up if $\alpha > 0$. Secondly, the firm under-invests because of externalities. This is illustrated by the fact that the severity of the under-investment increases with the degree of generality of the human capital δ. To see this, suppose that the worker has no bargaining power ($\alpha = 0$) and under-investment because of hold-up is thus ruled out. The

first-order condition under asymmetric information (3) then becomes $1 - q = c'(s)$. If training is completely specific ($\delta = 0$), then the firm's investment will be socially efficient. If training is general ($\delta = 1$), then the firm will under-invest. The intuition lies in the fact that the investment has positive externalities (if $\delta > 0$) that increase with δ. The training firm does not internalize these externalities and under-invests. This mechanism is identical to the one in Stevens (1994b).

6.1.2 *Ability Not Observable by Outside Employers*

Another information asymmetry that may lead to firm-sponsored general training investment occurs if current employers are better informed about the abilities of their workers than potential future employers. Adverse selection then dampens the response of market wages to human capital investments. This idea can be traced back to Greenwald (1986), who applied the adverse selection problem described in Akerlof (1970) to labour markets. He noted that employers may find it beneficial to finance general human capital accumulation of their workers as, 'adverse selection with its entry-level bonuses and tendency to tie workers to firms would rule out [these] possible job-changes and rationalize such investments by firms'.

Chang and Wang (1995) were the first to present a formal model with adverse selection and training. The adverse selection model that follows can be found in Acemoglu and Pischke (1999b). Figure 5 shows the order of events. Workers are heterogeneous in ability η, with probability p a worker is of low ability ($\eta = 0$) and with probability $1 - p$ the worker is of high ability ($\eta = 1$). Productivity of a worker after training equals $y_2 = \eta s$, and training and ability are therefore complements in production. Ability is not observed by the firm or the worker at the moment of hiring. The firm offers a first-period wage that the worker can accept or reject. Because ability is unknown at this point, the firm either offers training to all its workers or does not train at all. After the training ends, the firm observes the worker's ability and makes a second-period wage offer contingent on ability and training. The firm offers low-ability workers a second-period wage that equals their productivity ($w_2 = 0$) and high-ability workers the market wage ($w_2 = \overline{w}_2$, assuming that the firm has all the bargaining power).

Outside firms observe only the worker's training level s and not his ability. Their wage offer therefore depends only on s. The worker chooses to work for the party that offers him the highest wage. There is also exogenous turnover, with probability q (independent of ability), a worker quits the training firm and enters the market. As a result, there are at least some high-ability workers in the market.

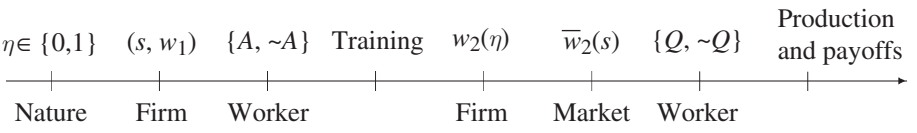

Figure 5. Timing of Events When Ability Is Not Observed by Outside Employers.

The expected productivity of a worker in the market is therefore strictly greater than the productivity of a low-ability worker. As a consequence, all low-ability workers will leave the training firm.

Assuming that workers get trained, then a fraction p of these workers is of low ability and profits for them equal $0 - \overline{w}_2$. These workers always separate because the market wage is higher than the wage offer from the incumbent firm. A fraction $1-p$ consists of high-ability workers and profits for them equal $s - \overline{w}_2$. These workers separate for exogenous reasons with probability q. This gives the expected profit for an outside employer:

$$\overline{\pi} = p \cdot (0 - \overline{w}_2) + (1-p) \cdot q \cdot (s - \overline{w}_2) \tag{4}$$

It is assumed that competition in the second period drives expected profits in the market to zero. This determines the equilibrium wage in the market for skills. Equating (4) to zero and solving for $\overline{w}_2$ gives the equilibrium market wage

$$\overline{w}_2 = \frac{(1-p)qs}{(1-p)q+p}$$

The training firm's profit function now becomes

$$\begin{aligned}\pi &= (1-q)(1-p)(y_2 - \overline{w}_2) - c(s) \\ &= (1-q)(1-p)\frac{p}{(1-p)q+p}s - c(s)\end{aligned}$$

The optimal investment level s^* is again strictly positive. The firm invests in technologically general training because it is able to earn a positive marginal return on this investment because the worker does not receive his full marginal product in the market.

A number of papers explore this information asymmetry and its consequences for human capital investment. Acemoglu and Pischke (1998) and Chang and Wang (1995) both presented models where adverse selection creates firm-sponsored human capital investment; in Acemoglu and Pischke (1998), training is contractable, whereas in Chang and Wang (1995), this is not the case. Acemoglu and Pischke (2000) presented a model in which workers have to exert effort for training to be successful. This creates a hold-up opportunity for the firm. The workers anticipating this will put forward suboptimal effort. Certification may be necessary to encourage workers to exert effort. Firms may then be willing to finance training. Schlicht (1996) and Su (1996) investigated what happens if the firm is subject to a moral hazard problem in training provision. Finally, Autor (2001) presented an asymmetric information model where credit-constrained workers can signal their ability through training choices; training therefore acts as a screening device and explains firms' (temporary help supply establishments in Autor's paper) investment in apparently general human capital.

6.2 *Other Sources of Market Imperfection*[19]

If it is costly for an employee to change jobs, the firm has some monopsony power and is able to capture part of the returns to training. If a worker quits, he has to

find a new match. Suppose that as a result of search frictions the worker succeeds but not always; he finds a new firm with probability $\lambda < 1$. If he finds a new job, he bargains over his wage with the new firm and $w_2 = \alpha y_2(s)$ (assuming Nash bargaining and bargaining power α). If the worker does not find a new job, he is unemployed and receives unemployment benefits $b(s)$. As a consequence, his expected market wage in the second period equals

$$\overline{w}_2 = \lambda\alpha y_2(s) + (1 - \lambda)b(s)$$

This serves as the worker's outside option when he bargains over his wage: $w_2 = \overline{w}_2 + \alpha(y_2 - \overline{w}_2)$. The firms profit function therefore becomes $\pi = (1 - \alpha)(y_2(s) - \overline{w}_2) - c(s)$. The first-order condition is

$$(1 - \alpha)((1 - \lambda\alpha)\, y'_2(s) - (1 - \lambda)b'(s)) = c'(s)$$

The marginal return to training for the firm is positive if $b'(s) < y'_2(s)$, which implies that the worker does not receive the full marginal return on his productivity in the unemployment benefits. This would imply full insurance which seems to be a weak condition, as most insurance systems are regressive.[20]

If general training is complementary to specific capital, the firm also has an incentive to invest in technologically general human capital. The complementarity makes that the productivity of the worker increases more in the incumbent firm than in the market. Note that the specific capital does not need to be specific human capital. If the general skills of the worker are complementary with specific physical capital, then the only requirement is that a new firm cannot buy additional physical capital and pay the worker his full marginal product. This again requires frictions of some sort, in particular credit constraints on the part of the new firm. The capital market imperfection therefore has spill-overs on the labour market.

As mentioned in section 3, if labour markets are competitive, then minimum wages lower general human capital investment because it may prevent workers from taking a wage cut to pay for this training. Now suppose that there are some frictions that in itself do not affect investment incentives: $\overline{w}_2 = y_2(s) - \Delta$, where Δ denotes, for example, fixed turnover cost. In this case, the worker still gets the full marginal product in the market. But now there is a minimum wage w_m. The second-period wage that the training firm pays is

$$w_2 = \max\{w_m, \overline{w}_2\}$$

If $\overline{w}_2 < w_m$ and $y_2 > w_m$, then the firm employs the worker at a wage $w_2 = w_m$ and therefore has an incentive to invest in general training, because the minimum wage is independent of the workers productivity. Market imperfections may therefore reverse the effect of minimum wages on general training investment.

A final example concerns unions. The basic idea is that, as unions compress wages among covered workers, this implies that the firm does not pay the most productive worker his full marginal product. The simplest case is the one in which all covered workers receive a uniform wage $w_2 = w$. The firm will then invest the efficient level, as $\pi = y_2(s) - w - c(s)$, and the first-order condition is

$y'_2(s) = c'(s)$. Note that if the workers are the investing party then union wage compression reduces their incentives to invest.[21]

7. Summary and Conclusion

This paper has presented a review of the economics of training. Standard competitive theory, as in Becker (1962), distinguishes between general training and specific training. General training is of equal value in many firms, whereas specific training is only useful in one firm. In this competitive world, workers reap all the returns to general training and consequentially finance it, either directly or through lower wages. Under-investment in general training occurs therefore only if workers are liquidity constrained. As firms will not finance general training, the negative poaching externality in which firms under-invest in general training because of the poaching of trained workers by other firms disappears. Finally, firms finance specific on-the-job training but might let workers share in the returns to reduce inefficient turnover.

The recent literature demonstrates how market imperfections may render training that is technologically general *de facto* specific because wages will be below marginal product. This restores investment incentives for technologically general training for the employer and may alleviate under-investment in such training. The poaching externality, however, reappears, as any source of imperfect competition leading to wages below marginal product, combined with any source of uncertainty about labour turnover, makes that the worker and the firm do not internalize positive externalities and under-invest.

It is difficult to arrive at unambiguous policy recommendations from the literature reviewed above. First of all, theory alone does not tell us whether and where there is (sufficient) under-investment to intervene. Under-investment crucially depends on the extent to which credit constraints and labour market imperfections impede investment, the practical significance of which, as Stevens (2001) points out, is difficult to assess.

A second complication in devising policy is that, depending on the particular market failure at work, solutions will differ. To illustrate this, take the example of training certification. The analysis of Katz and Ziderman (1990) showed that increased certification may lead to less investment in training by firms because training then becomes more visible to other employers. Acemoglu and Pischke (2000) on the other hand argue that certification may in fact be necessary to encourage firm-sponsored training if the success of training depends on the effort of workers. To arrive at a well-argued policy recommendation (certification or not), one would need to know which mechanism is more important in practice.

It is an empirical issue how the mechanisms reviewed above net out in practice. It is also an empirical question in which imperfections are important, where under-investment arises and where specifics will likely vary between markets. A challenging avenue for future research would be the unravelling of these issues empirically. This would further our understanding of training markets, close the

gap between theory and empirics and finally allow policy makers to effectively address real problems.

Acknowledgements

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Notes

1. Many of the ideas found in Becker are also present in Oi (1962).
2. From a modelling point of view, it will suffice to assume that there is one alternative employer.
3. One might wonder why firms provide general training to their workers and why there is no separate training market. Becker explained this by complementarities between learning and working (Becker, 1993, footnote 3, p. 34).
4. Acemoglu and Pischke (1999a) note that, if loan markets are not perfect and individuals smooth consumption, then wage cuts are costly and investment will not be efficient.
5. Here, it is assumed, without loss of generality, that in case of a tie the worker joins the training firm.
6. This sharing argument is also present in Oi (1962). See Parsons (1972) for an early formal discussion of the sharing hypothesis.
7. The firm and the worker could bargain over the surplus. Hashimoto, however, assumes that transaction costs are prohibitively high. Renegotiation could result in separation efficiency at the cost of investment inefficiency and transaction costs. Which of these two options is more expensive is an open question.
8. In the formulation of Carmichael (1983), quits are the result of low job satisfaction. The exposition here follows Becker *et al*. (1977) who argued that 'a quit could be said to result from an improvement in opportunities elsewhere and a layoff from a (usually unexpected) worsening in opportunities in this job . . . '. Unlike Becker *et al*. (1977), the model here allows inefficient separations.
9. Not discussed here are Hashimoto and Yu (1980) on wage indexing and MacLaughlin (1991) on the distinction between layoffs and quits.
10. Stevens (1994a), in a related model, considers jointly separation and investment efficiency. Instead of an exogenous stochastic market alternative for the worker, Stevens (1994a) models the labour market as a first-price sealed bid auction. As a consequence, the worker is no longer perfectly informed about his alternative value, and the outside firms behave strategically ($\overline{w}_2$ is no longer independent of w_2).
11. It may be impossible to write a contingent contract because investments may be too complicated or multidimensional.
12. See MacLeod and Malcomson (1993a), MacLeod and Malcomson (1993b) and Malcomson (1997) for models featuring hold-up in this vein.
13. Note that reputation does not play a role in the two-period models discussed here.
14. This resembles the analysis of Carmichael (1983) discussed above, although in his analysis wages could be attached to job titles, whereas it is crucial here that wages are attached to tasks.
15. With Inada conditions, $y_2(0) - \overline{w}_2(0) > 0$ is sufficient.
16. See also Acemoglu and Pischke (1999a) for a review of this literature.

17. Chang and Wang (1995) is a related model where future employers are also uninformed about workers' abilities.
18. To simplify notation, we also use q to refer to the event of a separation.
19. Acemoglu and Pischke (1999b) give many examples of market frictions leading to firm-sponsored general training, this section discusses some of them.
20. See the appendix of Acemoglu and Pischke (1999b) and Acemoglu (1997) for more details.
21. Booth and Chatterji (1998) present an alternative model where the presence of a union solves hold-up of the workers by the firm.

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