Equilibrium Contracts and Firm-sponsored Training

By Pontus Rendahl[†]

September 19, 2011

Abstract. This paper studies a model of firm-sponsored investments in general human capital. When institutional settings permit simple contractual agreements that are consistent with *at-will* employment, firms invest in a worker's general skills. When market-forces discipline contracts, equilibrium training intimately relates to *any* match-specific component of productivity, such as mobility costs. If these relation-specific components are sufficiently large, all externalities may be internalized, and training attains the social optimum. In contrast to the existing literature, none of these predictions rely on complementarities between training and match-specific components (e.g. "wage-compression"), and they are independent of the distribution of profits and wages. Lastly, I show that the recent surge in "tuition reimbursement programs" cannot be explained by the leading theory in the literature, despite the fact that these tuition programs generate a compressed wage structure. In contrast, equilibrium contracts yield Pareto-optimal training levels under a wide range of circumstances, even in the absence of any mobility frictions at all.

JEL-classification: D21, J24, J41, M52, M53

Keywords: Human capital; On-the-job training; Contracts and Reputations.

[†]Faculty of Economics, University of Cambridge; `pontus.rendahl@gmail.com`.

1. Introduction

Human capital is by many perceived as the main economic thrust in creating wealth and growth. Yet, investments in human capital is no trivial matter. Firms may shun devoting resources towards an asset as elusive as an employee, and workers themselves may lack the funding, access to credit, or even the possibility to invest without the consent of their employer. Despite this, a range of empirical studies document that firms do invest in the skills of their employees, and that the costs of such investments are borne by the employer, and not by the worker. This paper studies a firm's decision to provide, and pay for, human capital investments in a model of equilibrium contracts.

I find that a worker's *mobility* plays a key role shaping the provision of contracts and, ultimately, the amount of training observed. More precisely, match-specific components which restricts a worker's mobility limit renegotiations and permit firms to extract ex post *quasi*-rents. Competitive forces drive excess profits to zero, equating ex post rents with ex ante costs. As a consequence, the cost associated with the equilibrium level of training stands in direct parity with expected quasi-rents, which, themselves, intimately relate to the limitations to mobility. In marked contrast to previous studies, this result does not rely on complementarities between mobility-frictions and human capital, ruling out *wage-compression* as the main motivating factor. Furthermore, in an extension of the model I explore the implications of *tuition reimbursement programs* on training, and show that investments in general human capital attains the social optimum under a wide range of circumstances. Yet, firms ability to write contracts remains imperative. While reimbursement programs do induce a compressed wage structure, ex post wage-bargaining often falls short of providing the correct incentives to provide *any positive level* of training. As a consequence, this paper shows that under very naturally emerging circumstances, wage-compression is neither a necessary nor a sufficient condition to encourage firm-sponsored investments in general training.

In his seminal study, Becker (1964) drew a sharp distinction between *general* and *firm-specific* human capital. General skills are defined as those which are equally useful inside and outside an employment relation. Specific skills are, on the other hand, only useful within the context of the current job. Becker argued that in a competitive market, workers can seamlessly transition across employers, ensuring that wages, at a minimum, reflect their *outside* marginal product. The worker is therefore the sole residual claimant to any investments in general skills, mercilessly compromising the firm's willingness to provide the necessary training. With firm-specific human capital, however, the story is, at least partially, reversed. Firms, and not workers, are likely to lay any residual claims, and will therefore also devotedly provide the required funds. Casual observations largely confirms Becker's propositions. Workers optimally invest in their own general skills through schooling, while firms provide firm-specific human capital by means of on-the-job training. As both agents' incentives are aligned with societal preferences, Becker concluded that training is efficient.

Becker's predictions has not, however, gone by unchallenged. Workers may, for instance, face borrowing constraints or other institutional restrictions questioning the extent to which they can efficiently invest in schooling. Training is moreover often an intangible process of mentoring, learning by doing, advice and practice, largely beyond the control of the employee herself. Indeed, a recent empirical literature has shown that firms, and not workers, commonly do provide and pay for investments in general training, casting doubt on some of the literature's initial conclusions.

Using survey data, Barron, Berger, and Black (1997) and Bishop (1996) show that on-the-job training often displays a very general nature, and is commonly paid for by the employer. Productivity rises much faster with respect to training than wages – at a factor of around ten – suggesting that firms may reap large rewards investing in workers' skills.[1] Loewenstein and Spletzer (1998) find that in more than 40% of cases, firms pay for the explicit costs involved in off-site training – such as at business schools or vocational institutes – which is almost surely of a general character. Wage-growth, on the other hand, appears largely unaffected, suggesting that firms both pay for, and benefit from, investment in general human capital. Interestingly, the wage-growth associated with training provided by previous employers is much larger, giving further support to the general nature of acquired skills.[2] Another lucid example of firm-sponsored training stems from the German apprenticeship system (see, for instance, Harhoff and Kane (1995) and Franz and Soskice (1995)). In Germany, firms voluntarily offer apprenticeships to young workers which then undergoes extensive training. An apprentice's skills are verified by external boards upon completion, indicating a substantial general component. Although apprentices normally receive lower wages than fully trained workers, the net-cost of apprenticeships is consistently estimated to be strictly positive (e.g. Soskice (1994), Acemoglu and Pischke (1999b)). Despite this, apprentices are under no contractual obligation to remain with the firm providing training, exposing firms to the vulnerable situation initially suggested by Becker. So why do firms train?

This paper argues that the presence contracts together with frictional job-to-job transitions provide a fertile environment for firm-sponsored general training. To illustrate this idea, it is instructive to think of a contract simply as a wage agreed upon at the onset of a relationship. Because the worker is not contractually tied to her employer, the contract

[1]Bishop (1991) and Barron, Black, and Loewenstein (1989) reaches similar conclusions.

[2]Booth and Bryan (2005) and Blundell, Dearden, and Meghir (1996) find similar results in the United Kingdom, Gerfin (2004) in Switzerland and Goux and Maurin (2000) in France.

may be renegotiated, as the worker otherwise may threaten to leave. Renegotiations, however, occur only by *mutual consent*, ensuring that any reformulated agreement matches, but never exceeds, a worker's outside option.[3] As a consequence, if renegotiation occurs, any additional marginal increase in training will be fully reflected in wages, leaving the worker, but not the firm, the full residual claimant. More importantly, however, if renegotiation does *not* occur, the situation is instead the reverse. The firm, but not the worker, will instead reap the full marginal benefit associated with the additional provision of training. Evidently, a profit-seeking firm will find it optimal to invest in a worker's skills to the point of renegotiation, but never beyond.[4]

If training is of a perfectly general nature, a worker's outside option equals her marginal product less some cost of transition.[5] As an optimal provision of training implies that wages equal outside options, a firm's quasi-rent must exactly coincide with a worker's mobility cost. Ex ante costs, however, relate to the precise level of training, which in turn depends on the contract itself. A more generous contract yields more training, higher ex ante costs, and therefore lower total rents, and vice versa. An equilibrium contract must therefore induce a training-level such that the cost associated with its provision exactly equals the quasi-rents later accrued. I show that there exists a unique contract satisfying these properties. The *poaching externality* suggested by Becker can largely be internalized.

In an influential study, Acemoglu (1997) argues that the Beckerian poaching externality may not be the only source of market-failure plaguing an efficient provision of human capital. The mere possibility of *exogenous* separations may impede training further, as future firms would then reap the rewards of investments made by past employers. The argument applies quite forcefully to the preceding analysis: Even if wages were never to be renegotiated, exogenous separations instill a wedge between the (expected) private and societal residual gains, severely impairing a firm's willingness to train. Yet I show that if contracts assume the more complex role of a *value*, rather than just a wage, *all* externalities may be internalized. To appreciate this, notice that whereas a firm's expected private gain to training is reduced by the probability of separation, the worker's private gain is improved by the precise same amount; what the firm expects to forgo, the worker expects to retain. General training therefore turns into an attractive component of an optimal compensation package. A marginal increase in training improves a worker's job-satisfaction and ultimately allows the firm to marginally lower wages while still remaining equally competitive in the market for labor. Of course, inasmuch a *value* more resembles an expectation than a

[3]This particular form of renegotiation is further explained in Section 2, page 6. See MacLeod and Malcomson (1993) for a more advanced discussion.

[4]Or, if contracts are sufficiently generous, a firm will train to the socially optimal level, but not beyond.

[5]More generally, less of some relation-specific component to productivity.

formal contract, it is unclear whether a market economy may sustain such a reputational equilibrium. If firms are sufficiently patient, I show that it can.

In a recent sequence of papers, Acemoglu and Pischke (1998; 1999a; 1999b) seek to explain possible motives underpinning the observed pattern of training. While they do consider the possible consequences of labor mobility costs, their conclusions are diametrically different from here. Mobility costs establish a wedge between a worker's marginal product and her outside option giving rise to a situation of bilateral monopoly. Although firms may, in this case, extract some rents from their employees, Acemoglu and Pischke forcefully argue that such frictions are unable to improve firms' incentives to provide training.[6] If mobility costs are fundamentally unrelated to skills, so are rents, and the *marginal* cost to training exceeds the *marginal* benefit even at very low levels of human capital. Instead, Acemoglu and Pischke assert that a worker's marginal product must rise faster with training than her outside wage in order to provide firms with the right incentives to invest. The underlying *wage-compression*, they conclude, is both necessary and sufficient for firm-sponsored training, an assertion markedly in contrast with the ideas developed in this paper.

Acemoglu and Pischke provide a battery of explanations which may potentially underpin a compressed wage structure. Following Katz and Ziderman (1990), Chang and Wang (1996), and later Autor (2001) and Malcomson, Maw, and McCormick (2003), they show that asymmetric information with respect to skills or training may lead to a distorted external wage structure.[7] Efficiency wages and/or union wage-setting provide additional foundations to a compressed wage structure, and may therefore also encourage firms to invest in an employee's general skills. And search frictions may plausibly have a similar effect on workers' outside opportunities, on wages, and therefore, ultimately, on training. Interestingly, Acemoglu and Pischke further contend the common-held view that access to firm-specific human capital may suppress investments in general skills, as firms' residual benefits are more favorably inclined to the former. In contrast, they argue that if (and only if) firm-specific and general human capital are complementary in production, investments in firm-specific skills compress the external wage structure, and therefore encourages more – and not less – investments in general training.

Under the more challenging hypothesis in which firm-specific and general human capital are perfectly substitutable, I further analyze the equilibrium outcome of training. While

[6]For instance, Acemoglu and Pischke (1999a) note that "It is not the attachment between firms and workers that leads to firm-sponsored training".

[7]It should be noted here that asymmetric information may generate a distorted wage structure if skills and human capital are complements in production, but not otherwise. Furthermore, Autor (2001) provide a slightly differentiated analysis compared to others. In particular, Autor consider the training-phase an opportunity for a firm to expose informational asymmetries.

the social optimum prescribes zero investments in specific skills and positive investments in general skills, the *market outcome* in the framework of Acemoglu and Pischke suggests the precise opposite.[8] In contrast, I show that under the hypotheses laid out in the present study, the aforementioned results still remain valid, with little modification. Firms optimally invest in a worker's general skills, equating the cost of training with expected quasi-rents. Quasi-rents, however, are now generally larger than previously, as even a small investment in firm-specific human capital magnifies any costs to transition, creating further room for investments in general training. While substitutes in production, general and firm-specific skills are complementary from a strategic point of view. Mobility costs again amplify the provision of training further, but they are by no means necessary.

In the latter part of the analysis, I consider the implications of tuition reimbursement programs on firm-sponsored training. Employer provided tuition reimbursements is a widespread program in which firms provide financial assistance for the direct cost of coursework taken by employees.[9] As training is conducted at accredited academic institutions, there is little doubt on the general nature of acquired skills. Participation in training programs, however, is commonly subjected to repayment clauses, which stipulate reimbursement of incurred training costs if the worker were to separate before some contracted minimum service period. As an increase in training directly translates to a larger separation repayment, the *external* wage structure – i.e. the worker's threat point – is tightly compressed. Yet, absent of contracts, the resulting compression fails to provide firms with the right incentives to train.[10] To appreciate this, notice that an increase in training increases separation repayments, and therefore also a firm's quasi-rents. By cause of bargaining, however, the increase in expected quasi-rents is likely to fall short of the associated increase in separation repayments, which – *at the very most* – equals the marginal cost. Thus, while investments in training does engender an increase in firms' quasi-rents, the marginal gain of such policy is unlikely to exceed the marginal cost, even at zero levels of training. In contrast, equilibrium contracts yields Pareto-optimal investments in training under a wide range of circumstances, including the situation in which there are no (exogenous) mobility costs at all.

2. Model

The economy is populated by a large number of potential firms, and a unit-measure of workers. Workers live for one period, after which they are replaced by a new cohort of equal

[8] In Acemoglu and Pischke's framework, if the two types of human capital are perfectly substitutable, the market outcome predicts zero investments in general skills, and positive investments in firm-specific skills.

[9] Capelli (2004) estimate that up to 85% of firms offer some form of tuition reimbursement program.

[10] Or, equivalently, no tuition reimbursement programs would be offered.

size. Firms, on the other hand, may live for perpetuity, and survive from one period to the next with probability $\beta \in (0, 1]$.[11] Both workers and firms are assumed to be risk-neutral.

In each period, a firm will decide whether to assume the role of a *training-firm* or of a *poacher*. There is no cost associated with the choice of characteristics, and any decision is perfectly reversible in future periods. A training-firm may offer a worker training, τ, before she enters her productive period. Undergoing training instills no disutility per se, and is therefore always accepted. Whereas training, of course, improves a worker's marginal product, $f(\tau)$, it also comes at cost $c(\tau)$. Functions f and c are assumed to be strictly increasing, strictly concave, with $c(0) = 0$. The socially optimal level of training, τ^*, is assumed to be strictly positive and is defined by $\tau^* \coloneqq \text{argmax}\{f(\tau) - c(\tau)\}$.[12]

In contrast to a training-firm, a poaching-firm does not offer any investments in human capital. Instead they aim to attract previously trained workers right before their productive period. As employment is formed and sustained on an *at-will* basis, a worker may legally leave her current employer if she finds a poacher's offer more favorable. The general nature of training ensures that a worker's marginal product remains intact. However, by separating from her current employer, a worker will incur cost $\Delta \geq 0$, *irrespective of her level of human capital*, τ.[13] A successful poach must therefore always entail a wage which exceeds the value of staying by, at least, this cost of transition. The mobility cost, Δ, may have a very broad interpretation. It could represent the disutility, spousal constraint, or monetary cost of relocating. But as we shall see, it could also represent some match-specific component of productivity – e.g. firm-specific human capital – which is then lost at transition.

With probability $q \in [0, 1)$ a worker and her training-firm will separate regardless of a poacher's offer. Separation occurs before the worker's productive period, but after the training-phase. The training-firm then immediately turns into a poaching-firm, matching with a new, separated, worker. Analogously, the worker will immediately team-up with a new poaching-firm. The underlying shock to the relationship is thought to parsimoniously capture the idea of a separation externality, in which future employers benefit from past employers' training decisions (Acemoglu, 1997). Separation, in this case, is ex post efficient, but it will entail distortionary effects on ex ante training decisions.

[11]The survival-rate β may of course also double as a discount factor. Or more generally, β may represent the product between some exogenous survival-rate, $\lambda < 1$, and discount factor, δ, such that $\beta = \lambda \times \delta$. But none of these details are important for the analysis.

[12]Sufficient conditions to ensure $\tau^* > 0$ are that f and c are differentiable and that $f'(0) > 0$, $\lim_{\tau\to\infty} c'(\tau) = \infty$, and $c'(0) = 0$.

[13]It should be noticed that this is a substantial departure from the studies of Acemoglu and Pischke, in which Δ is positively related to τ.

Lastly, as neither firms nor workers are contractually tied to the partnership, renegotiations may arise. Any previously agreed contract is, nevertheless, enforceable as long as trade does take place, and renegotiation can therefore only occur by *mutual consent* (MacLeod and Malcomson, 1993). Renegotiation by mutual consent observes two important properties. First, if trade under the current contract is mutually beneficial, renegotiation will never arise. Second, whenever renegotiation does arise, any reformulated agreement exactly matches, but never exceeds, an agent's outside offer.[14]

The argument can be made simple. Suppose that post training, the firm suggests a new revised wage-contract to the worker.[15] The worker can either accept or reject the offer, or leave the firm in favor for some outside opportunity (i.e. a poacher). If the offer is rejected, trade will materialize under the previously agreed contract. If it is accepted, trade will instead take place under the newly suggested contract. Lastly, if the worker leaves, the partnership is terminated. Clearly, any offer yielding a lower value to the worker than that associated with the current contract will be rejected. Any offer falling short of an outside opportunity will terminate the match. And any offer above the current contract *and* the outside option will be suboptimal from the firm's perspective. As a consequence, a firm will either propose to leave the current contract intact, or suggest a reformulated agreement which exactly matches, but does not exceed, the worker's outside offer.

Given such a renegotiated contract, suppose the worker has the opportunity to suggest yet another revision. Any value lower than the previously revised contract is of course sub-optimal from the worker's perspective, and will therefore never be suggested.[16] And any higher value will always be rejected by the firm. As a consequence, the firm's initial revision – if any – will prevail and ultimately dictate the terms of trade.[17]

The within period time-line of events is illustrated in Figure 1. In the beginning of the period, the firm and the worker sign a contract. Uncertainty is resolved after the training-phase, at which the partnership is liquidated with probability q. With the complementary probability $1-q$, however, the partnership remains intact, but the prospect of poaching may still engender voluntary quits, and therefore also renegotiations. In any event, the worker reaches her productive phase in the latter part of the period, and the monetary transaction is executed.

[14]This property is commonly known as "the outside option principle".

[15]Notice that as renegotiation occurs after the training-phase and after uncertainty is resolved, the relevant part of the contract that may be renegotiated is simply the wage.

[16]Although in the event it would be, it would also always be accepted by the firm.

[17]MacLeod and Malcomson (1993) studies a more intricate version of this renegotiation game, in which the proposer is randomly drawn on multiple occasions. As the length of each time-interval approaches zero, the firm will become the proposer with probability one, and the result follows.

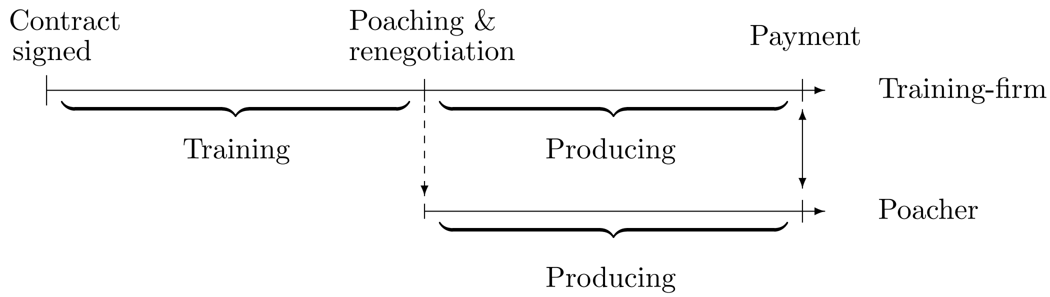

FIGURE 1. Time-line of events.

2.1. **Equilibrium.** A potential firm opens up a vacancy at cost $k \geq 0$, irrespective of her subsequent choice of characteristic. The cost k may denote the actual cost of posting a vacancy, but it could also represent the returns to some unmodeled factor of production such as physical-capital, entrepreneurial returns, or the cost of management. There are no matching frictions, and as long as a firm subscribes to the going market price for labor, V, her vacancy will be filled immediately and with probability one. Training-firms are, therefore, price takers. Poachers, on the other hand, are by definition uninterested in filling a vacancy immediately. Instead, they attempt to headhunt workers *after* the training-phase by outbidding incumbent employers by at least Δ.

Before formally defining a competitive equilibrium, it is instructive to discuss some of its more relevant implications. An equilibrium implies that the demand for labor – i.e. the number of active firms – equals the supply of labor, which, by assumption, is of measure one. As a fraction, $1 - \beta$, of firms exogenously exit each period, a corresponding measure of firms must enter in order to (intertemporally) sustain an equilibrium. Obviously, if the expected net present value profits exceed the up-front cost k, the measure of active firms will be ever expanding. Conversely, if the aforementioned profits fall short of the cost k, the measure of active firms will be ever declining. If, and only if, ex ante profits precisely equal the entry cost k, the measure of active firms – or labor demand – is left undetermined, and will therefore, in equilibrium, equal labor supply.

If we for the moment assume that an equilibrium exists in periods $t + 1$ onwards, a (successful) poacher's profits in period t must equal

$$\pi = f(\tau) - w + \beta k \tag{1}$$

where w denotes the wage paid to the worker. If a poacher could successfully attract workers at a wage $w < f(\tau) - (1 - \beta)k$, ex ante profits would exceed k, and the measure of active poachers would be ever expanding. Bertrand competition would immediately put upward pressure on wages until $w = f(\tau) - (1 - \beta)k$, ensuring that $\pi = k$. Conversely, no poacher would ever offer a wage $w > f(\tau) - (1-\beta)k$, as ex ante profits would fall short of k. There would be no endogenous entry of poachers, and the remaining – and exogenously determined – measure of poaching-firms, q, would be matched by an exogenously laid off worker even at wage $w \leq f(\tau) - (1-\beta)k$.[18] As a consequence, the only poaching wage prevailing in equilibrium is given by $w = f(\tau) - (1-\beta)k$, which ensures that ex ante profits exactly matches any upfront costs. As a final remark, it should be noted that a training-firm always finds it profitable to renegotiate and match a poacher's offer, were it to exceed the initially agreed contract.[19] As a consequence, the equilibrium will not observe any voluntary – or endogenous – separations.

The market price for labor, V, takes the form of a *value*.[20] More precisely, with a slight abuse of notation, let w denote the wage paid at a training-firm. A worker's evaluation of the value of employment is then given by

$$V = (1-q)w + q(f(\tau) - (1-\beta)k - \Delta) \tag{2}$$

That is, with probability $1-q$, the relationship is left intact and the worker may enjoy the wage w. With the complementary probability q, she will instead team-up with a poacher and receive $f(\tau) - (1-\beta)k - \Delta$.

Conditional on having entered the market, a training-firm's problem can now be formulated as

$$\pi(V) = \max_{w,\tau \geq 0} \{(1-q)(f(\tau) - w + \beta k) - c(\tau) + qk\} \tag{3}$$

$$\text{s.t.} \quad V \leq (1-q)w + q(f(\tau) - (1-\beta)k - \Delta) \tag{4}$$

$$w \geq f(\tau) - (1-\beta)k - \Delta \tag{5}$$

Equation (3) represents a firm's expected net present value profits. The first term captures revenues and costs accruing under the hypothesis that no separation occurs. It includes the worker's marginal product $f(\tau)$, her wage w, and expected continuation profits βk, respectively. With probability q, however, the firm and the worker separate, and the firm – assuming the role of a poacher – is assured profits k. In any case, the firm has to pay the full training cost $c(\tau)$.

Equation (4) – the "promise-keeping" constraint – ensures that the firm will not renege on delivering the value specified by the contract, V. Of course, inasmuch as training, and

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[18] It should be noted that search, in this case, is assumed to be undirected.

[19] Notice that a training-firm's profits *after the training-phase* equals *at least* k if a poacher's offer is matched, and only βk is the worker is lost to the poacher.

[20] Notice however that alternative contracts will be considered in later parts of the paper.

maybe also wages, are difficult to verify by some third party (a court), commitment issues may arise as a relevant concern. These concerns will be addressed in Section 3.1.

Lastly, equation (5) guarantees that wages are renegotiation-proof. Permitting workers to renegotiate wages, or allowing firms to optimally set wages that never are, are entirely isomorphic in this setting. The latter formulation, however, yields slightly simpler notation and a more straightforward analysis.

It is worth emphasizing here that the parameter Δ need not to denote a mobility cost per se, nor must it specifically be levied on the worker. Indeed, Δ may well represent some firm- or match-specific component to productivity which is then lost in case of separation. As the consequences of such an alteration is purely rhetorical, problem (3)-(5) remains, of course, unaffected.

The definition of a competitive equilibrium is now straightforward.

Definition 1. *A competitive equilibrium is a contract V such that,*

(i) Given V, τ and w solve (3)-(5)*.*
(ii) Firms make profit k. That is, $\pi(V) = k$.

3. Results

Given the definition of a competitive equilibrium, we are now ready to state the paper's main proposition.

Proposition 1. *There exist a unique equilibrium with training satisfying,*

(i) $c(\tau) = (1-q)\Delta$ if $c(\tau^*) \geq (1-q)\Delta$,
(ii) and $\tau = \tau^*$ if $c(\tau^*) \leq (1-q)\Delta$

Proof. Rearranging constraint (4) yields

$$(1-q)w \geq V - q(f(\tau) - (1-\beta)k - \Delta)$$

Conditional on a certain choice of τ, a necessary and sufficient condition for optimal wage-setting is therefore given by

$$(1-q)w = \max\{V, f(\tau) - (1-\beta)k - \Delta\} - q(f(\tau) - (1-\beta)k - \Delta) \tag{6}$$

As a consequence, the objective function is strictly increasing on $\tau \in [0, \min\{\bar{\tau}, \tau^*\})$ – where $\bar{\tau}$ is defined as $V = f(\bar{\tau}) - (1-\beta)k - \Delta$ – and strictly decreasing thereafter. Optimal training is therefore given by $\min\{\bar{\tau}, \tau^*\}$. Optimal wage-setting combined with the optimal choice of training reveals that wages satisfy

$$(1-q)w = V - q(f(\tau) - (1-\beta)k - \Delta)$$

In equilibrium, however, firms make profits k, and V must therefore satisfy

$$V = f(\tau) - (1-\beta)k - c(\tau) - q\Delta \tag{7}$$

That is, the optimal level of training depends on the contract, V, and the equilibrium level of V depend on the optimal level of training.

Inserting the equilibrium V in equation (7) into the wage-setting equation (6) yields

$$\begin{aligned}(1-q)w = \max\{f(\tau) - (1-\beta)k - c(\tau) - q\Delta, f(\tau) - (1-\beta)k - \Delta\}\\ - q(f(\tau) - (1-\beta)k - \Delta)\end{aligned}$$

Combining the equation above with the optimal choice of training implies that if $c(\tau^*) \geq (1-q)\Delta$, the unique equilibrium is given by $c(\tau) = (1-q)\Delta$. And if $c(\tau^*) \leq (1-q)\Delta$, the unique equilibrium is given by $\tau = \tau^*$. $\square$

The details of the proof are quite involved and best understood algebraically, but the logic is straightforward. Suppose for simplicity that both k and q equals zero. That is, there is no uncertainty and the equilibrium entails that firms make zero profits. A contract, V, is then simply an agreed wage. As a consequence, a firm may seize *all* residual gains associated with training up until the point of renegotiation, but *none* thereafter. The optimal choice of training is therefore given by $\min\{\tau^*, \bar{\tau}\}$, where τ^* denotes the social optimum, and $\bar{\tau}$ the level of training at which renegotiation is imminent.[21] The optimal wage, in turn, is given by the contract V itself, as either $\tau = \tau^*$ – and no renegotiation occurs – or $\tau = \bar{\tau}$, at which $V = f(\bar{\tau}) - \Delta$ and renegotiations are imminent. Of course, inasmuch as the renegotiation-point of training, $\bar{\tau}$, depends on the contract, V, so does also the optimal choice of training.[22] But whereas training relates to contracts, zero profits infer that an equilibrium contract itself relates to training. More precisely, after the training-phase, firms earn quasi-rents $f(\tau) - V$. Total rents, or expected profits, are given by $f(\tau) - c(\tau) - V$. Hence, an equilibrium contract must satisfy $V = f(\tau) - c(\tau)$.

Figure 2 illustrates the relationship between contracts and training at two different levels of the mobility cost. Consider first the graph to the left. The monotonically increasing curve marked as $f(\bar{\tau}) - \Delta$ traces out the renegotiation-point, $\bar{\tau}$, as a function of the contract, V. Again, for a certain contract, the optimal choice of training is given by $\min\{\bar{\tau}, \tau^*\}$. The other curve, the parabola marked $f(\tau) - c(\tau)$, illustrates instead the contract which ensures zero profits at various values of τ. By the assumptions on f and c, there exist a unique intersection-point at which $V = \bar{V}$ and $\tau = c^{-1}(\Delta)$. That is, at the contract $\bar{V}$, the optimal choice of training is given by the renegotiation-point $\bar{\tau} = c^{-1}(\Delta)$, as $\bar{\tau} < \tau^*$. And at

[21]For a given V, $\bar{\tau}$ is defined by $V = f(\bar{\tau}) - \Delta$.

[22]Recall that the optimal choice of training is given by $\min\{\tau^*, \bar{\tau}\}$.

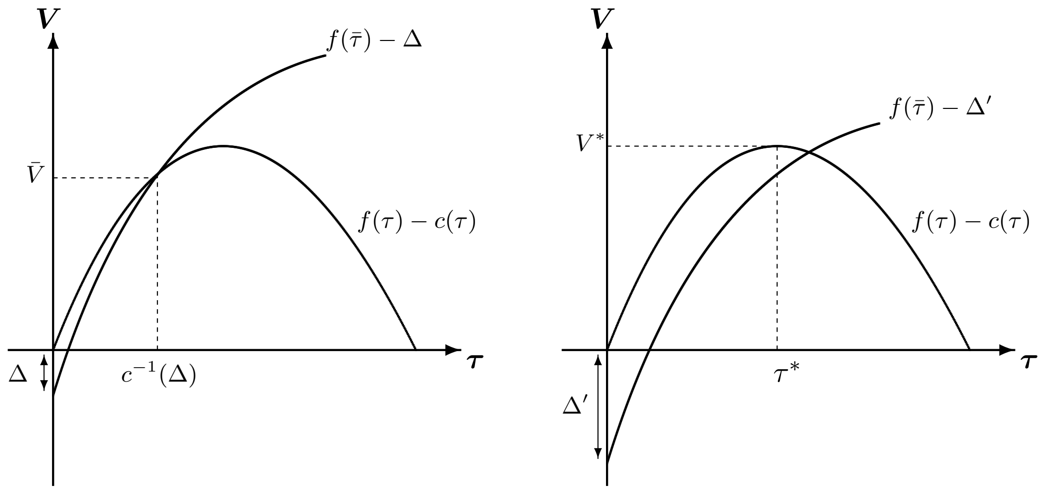

FIGURE 2. The relationship between contracts and training.

training-level $c^{-1}(\Delta)$, the contract $\bar{V}$ ensures zero profits. As a consequence, the contract $\bar{V}$ is the unique equilibrium contract, and $\bar{\tau} = c^{-1}(\Delta)$ is the unique equilibrium level of training.

The distinct relationship between the equilibrium level of training and the mobility cost, Δ, is also easily understood in the current context. As $\bar{\tau}$ is strictly below τ^*, renegotiation is imminent, and $\bar{V} = f(\bar{\tau}) - \Delta$. The firm's ex post quasi-rents are therefore simply given by the cost Δ.[23] As firms make zero profits under contract $\bar{V}$, the cost of training, $c(\bar{\tau})$, must equal the quasi-rent Δ, and $\bar{\tau} = c^{-1}(\Delta)$ follows.

The graph on the right of Figure 2 illustrates the same aforementioned relationships but at the larger mobility cost Δ'. For a given level of V, a larger cost to mobility raises the renegotiation-point, expands the scope for training, and shifts the curve $f(\bar{\tau}) - \Delta'$ to the right. At the contract V^*, the renegotiation point of training, $\bar{\tau}$, widely exceeds the social optimum, τ^*, which therefore coincides with a firm's preferred investment level. Of course, as V^* is defined as $f(\tau^*) - c(\tau^*)$, firms make zero profits, and the equilibrium level of training corresponds to the social optimum.

As a final remark, it should be noted that assuming zero profits is largely innocuous from the perspective of illustrating the equilibrium, but abstracting from uncertainty is not. Whenever q is positive, the equilibrium displays exogenous separations at which future employers benefit from past employers' training decisions, and contracts assume the more elaborate role of a value, rather than just a wage. To better understand the implications of such exogenous separations, let us for the moment ignore constraints (4) and (5). The first-order condition of the firm's objective function with respect to training is then given

[23]Recall that a firm's quasi-rents are defined as $f(\tau) - V$. Hence $f(\bar{\tau}) - \bar{V} = \Delta$.

by

$$(1-q)f'(\hat{\tau}^*) = c'(\hat{\tau}^*) \tag{8}$$

where $\hat{\tau}^*$ denotes the, for lack of a better word, *constrained efficient* level of training.[24] Thus, even in the absence of the poaching externality, the separation externality imposes a wedge between the private and societal returns to training, casting *prima facie* doubt on the efficiency of the equilibrium. Despite this, Proposition 1 reveals that such concerns are unnecessary. To understand why, combining constraints (4) and (5) reveals that optimal wage-setting observes

$$(1-q)w = \max\{V, f(\tau) - \Delta\} - q(f(\tau) - \Delta)$$

Thus, under the hypothesis that renegotiation is not locally an imminent threat – i.e. that $V > f(\tau) - \Delta$ at some τ – wages are actually *decreasing* in training. As investments in general human capital improves a worker's situation in case of separation, it also improves her job-satisfaction, and therefore permit firms to lower wages while still remaining an attractive and competitive employer. A marginal increase in training yields a direct benefit by raising an employee's expected marginal product by $(1-q)f'(\tau)$, but it also yields an indirect benefit of marginally lowering wages by $qf'(\tau)$. The total marginal benefit is therefore $f'(\tau)$, and the separation externality can be internalized. Investments in general human capital constitute an attractive component of an optimal compensation package.

However, while the separation externality can be internalized from a marginalist perspective, it does impair training at sufficiently low levels of Δ. To appreciate this, notice that when renegotiation is imminent, a firm's ex post quasi-rent still remains equal to Δ. *Expected* quasi-rents, however, equal only $(1-q)\Delta$. As a consequence, training satisfies $c^{-1}(\Delta(1-q))$ if $c(\tau^*) \geq (1-q)\Delta$, and coincides with the social optimum only if $c(\tau^*) \leq (1-q)\Delta$. Therefore, and as in Acemoglu and Pischke (1999a), higher turnover reduces training.

3.1. **Reputations.** The previous section studied a model in which firms can commit both to training and wages. While it appears reasonable that a court is able to verify and enforce contracts which stipulate a monetary transaction, the more elusive nature of training raises some further challenges. In particular, as training commonly involves the highly intangible (and unverifiable) process of mentoring, learning by doing, advice and practice, past commitments may be honored only through participants voluntary actions, or perhaps not at all.

[24] For illustrational purposes it is here assumed that f and c are differentiable functions. If they are not, the constrained efficient level of training is defined as $\hat{\tau}^* := \text{argmax}\{(1-q)f(\tau) - c(\tau)\}$

This section will address these concerns. First, under the hypothesis that no firm can, nor will, commit to training, I examine to which extent investments in general human capital can be sustained in equilibrium. As we shall see, training need not to differ markedly from the previous analysis, but it will neither ever reach the social optimum. Second, I examine under which conditions firms may voluntarily honor past training committments, even in the absence of third party enforcement. If firms are sufficiently "patient", i.e. $\beta \to 1$, I show they will.

If firms are not able, or willing, to honor past training commitments, a contract assumes the *de facto* role of a simple wage. That is, constraint (4) in problem (3)-(5), is replaced by

$$V \leq w \tag{9}$$

where V again denotes the contract, and w the resulting, renegotiation-proof, wage. Let $\hat{\tau}^*$ again represent the constrained efficient level of training; i.e. $\hat{\tau}^* := \text{argmax}\{(1-q)f(\tau) - c(\tau)\}$. Proposition 2 then summarizes the equilibrium outcome.

Proposition 2. *There exist a unique equilibrium with training satisfying,*

(i) $c(\tau) = (1-q)\Delta$ *if* $c(\hat{\tau}^*) \geq (1-q)\Delta$*,*

(ii) and $\tau = \tau^*$ *if* $c(\hat{\tau}^*) \leq (1-q)\Delta$*.*

Proof. In Appendix A. □

Thus, in the absence of contracts stipulating both wages as well as human capital investments, firms may train up until the constrained efficient level, $\hat{\tau}^*$, but never beyond. Shortly put, the separation externality cannot be internalized. Nevertheless, for a sufficiently small level of the mobility cost, training under the two contracting regimes coincide exactly, as the poaching externality – and not the separation externality – is the dominating market failure, impairing any investments beyond $c^{-1}(\Delta(1-q)) \leq \hat{\tau}^*$.

However, whereas firms may renege on unverifiable commitments without legal consequence, there are also reasons to believe that market forces alone can in some circumstances sustain contractual performance. Following the ideas developed in Klein and Leffler (1981), consider the situation in which courts are unable to verify the intricate nuances that constitute training, but parties involved in the transaction can. A worker whose employer has not conformed to the market-anticipated training provision may then publicly communicate her discontent, permanently tarnishing her employer's reputation. As a consequence, a firm defecting on her training promise may face significant difficulties attracting future employees, providing strong incentives to honor even unverifiable agreements. I will henceforth refer to such a situation as a *reputational equilibrium.*

Proposition 3. *A reputational equilibrium can be sustained for some* $\beta \in (0, 1)$*.*

Proof. In Appendix A. □

To appreciate the proposition, it is important to understand both the gains and losses associated with defection. A firm that has previously reneged on her training promise has permanently lost her ability to attract potential employees by committing to a *value*, V. Instead, she must offer a wage-contract, $\hat{w}$, such that the associated *perceived* value of employment equals that of the market.

Suppose that $c(\hat{\tau}^*) \geq (1-q)\Delta$. In the equilibrium with commitment, renegotiations are imminent and wages, w, are thus given by $f(\tau)-(1-\beta)k-\Delta$. As a consequence, a firm that has previously defected on her training promise may well offer the contract $\hat{w} = w$, and, optimally, train $\hat{\tau} = \tau$.[25] A defected firm behaves therefore no differently from a committed firm, and reputations are irrelevant. The reason is quite straightforward. As the poaching externality impedes human capital investments beyond $\hat{\tau}^*$, the separation externality does not interfere with equilibrium training, rendering contracts which encompass anything in excess to a simple wage redundant.

However, in the alternative scenario in which $c(\hat{\tau}^*) < (1-q)\Delta$, equilibrium training with commitment is instead given by $\tau > \hat{\tau}^*$. Any defecting firm offering $\hat{w} = w$ will therefore train up until the constrained efficient level, $\hat{\tau}^*$, but not beyond. The perceived value of employment is given by $(1-q)w+q(f(\hat{\tau}^*)-(1-\beta)k-\Delta)$, which falls short of the equilibrium market value, V. As a consequence, a firm that has previously defected would, in this case, not be able to attract any future employees, and therefore quickly run out of business.

Thus, in order to remain an attractive employer, a firm that has previously defected must offer a wage $\hat{w}$ such that

$$(1-q)\hat{w} = V - q(f(\hat{\tau}^*) - (1-\beta)k - \Delta)$$

ensuring that the perceived value of employment equals that of the market. Clearly, as $\hat{\tau}^*$ falls short of τ, $\hat{w}$ must exceed w, and a reneging firm will find herself less profitable in the future than a committed firm.

Nevertheless, while a defecting firm can be sure to make some future losses relative to a committed firm, reneging on past training-commitments also brings some immediate benefits. In particular, the *momentary* return for a defecting firm equals

$$(1-q)(f(\hat{\tau}^*) - w) - c(\hat{\tau^*}) + qk$$

By the definition of $\hat{\tau}^*$, these returns clearly exceeds those of a committed firm, and a reputational equilibrium can only be sustained if future losses exceed the momentary gains. Proposition 3 reveals that for a sufficiently large β, they do.

[25] Recall that both w and τ refers to the outcomes in Proposition 1.

3.2. **Firm-Specific Human Capital.** The preceding analysis has so far focussed on human capital provisions encompassing a perfectly general nature. However, it appears obvious that there exist other forms of human capital which are more useful within a specific employment relation. Although the existence of a purely firm-specific type of human capital is to some extent doubtful, this does not, in my view, undermine the usefulness of studying its theoretical implications.[26] For instance, the supply chains of many modern companies are comprised by several similar and often well-established steps. A worker's accumulation of human capital therefore covers industry-, or even economy-wide, components such as standardized softwares, machines, and structures – which are all surely of a general nature. Yet, this organization is not coincidental. A firm could well develop its very own unique supply chain, effectively constraining the accumulation of human capital to the firm's specificity. Thus, the mere fact that purely firm-specific human capital is rarely observed does not imply that it does not exist within a firm's choice-set. Indeed, the very presence of standardized – or "general-intense" – supply chains raises the same questions and challenges as those of firm-sponsored investment in general human capital. The Beckerian poaching externality appears to be an imminent threat even at this, much grander, scale.

Acemoglu and Pischke (1999a) explore the consequences of firm-specific human capital on the provision of general training. They conclude that *if and only if* both types of capital are complementary in production, firms find it optimal to – at least partly – invest in a worker's general skills. The mechanism is quite direct. As the presence of firm-specific human capital increases the marginal return to general training, but has no effect on a worker's external wage structure, the marginal net benefit of investments is positive and the result follows. It should be noted, however, that although training is positive under these assumptions, it does never – under realistic conditions – reach the social optimum.[27]

Suppose that a firm in the current framework has access to two types of human capital, τ and s. As previously, τ is of a perfectly general nature, while s is entirely firm-specific, and therefore lost in case of separation. In addition, the two different types of skills are

[26] For instance, Abraham and Farber (1987), Topel (1991), and Jacobson, LaLonde, and Sullivan (1993) find strong evidence in favor of a positive tenure premium, commonly interpreted as firm-specific human capital. However, Altonji and Shakotko (1987) and Altonji and Williams (2005) cast some doubts on these findings.

[27] General training reaches the social optimum in Acemoglu and Pischke (1999a) if and only if a worker's external wage-structure is entirely independent of general human capital. In the current setting, if both types of human capital are perfect complements – e.g. a Leontief production function – firm's train to the Pareto-optimum.

perfectly substitutable in both production and costs.[28] A training-firm's objective function is therefore given by

$$\pi(V) = \max_{w,\tau\geq 0,s\geq 0}\{(1-q)(f(\tau+s)-w+\beta k)-c(\tau+s)+qk\} \tag{10}$$

subject to, again, constraints (4) and (5).[29] The Pareto-optimal level of training is again given by $\tau = \tau^*$, and with $s = 0$.

Before stating the main proposition of this section, it is useful to define the unique number $s^* > 0$ as

$$s^* := \text{argmax}\{(1-q)f(\tau)-c(\tau)\} \tag{11}$$

It should be noted that s^* takes on the same value as $\hat{\tau}^*$, the contained efficient level of training, in the preceding section. Although, as they have very different interpretations, they do not share notation.

Proposition 4. *There exist a unique equilibrium with the following properties,*

(i) If $(1-q)\Delta < c(s^*)$, general training solves $(1-q)f(\tau)-(1-q)\Delta = (1-q)f(s^*) - c(s^*)$, and firm-specific training equals $s = s^* - \tau$.

(ii) If $c(\tau^*) > (1-q)\Delta \geq c(s^*)$, general training solves $c(\tau) = \Delta(1-q)$, and firm-specific training is zero.

(iii) Finally, if $c(\tau^*) \leq (1-q)\Delta$, general training equals τ^* and firm-specific training is, again, equal to zero.

Proof. In Appendix A. □

In order to understand the mechanisms underlying the proposition, it is instructive to derive the optimal choice of firm-specific human capital investments, s, as a function of general training, τ

$$s = \begin{cases} \text{argmax}\{(1-q)f(s+\tau)-c(s+\tau)\} & \text{if } \tau \leq s^*; \\ 0 & \text{elsewhere.} \end{cases}$$

That is, as long as $\tau \leq s^*$, s is set such that the sum $\tau + s$ satisfies (11). Clearly, if $\tau > s^*$, s equals zero as the non-negativity constraint is binding. However, for the very same reasons as discussed in Section 3, page 13, investments in general skills, τ, are marginally preferred to specific skills, s. That is, under the hypothesis that renegotiation is not an imminent threat, the marginal benefit to general training is given by $f'(\tau + s)$, to be compared with

[28]It should be noted that the assumption of perfect substitutes contrast markedly with previous studies (e.g. Acemoglu and Pischke (1999a), Kessler and Lülfesmann (2006), and Balmaceda (2005)), and effectively removes the direct link established between firm-specific and general human capital discussed above.

[29]As s is purely firm-specific, it does not show up in any of the constraints, which remains unaltered.

$(1-q)f'(\tau+s)$ for the equivalent (marginal) investments in specific skills. The cost, however, is the same. Thus, a profit maximizing firm will invest in general skills up until the point of renegotiation – or to the Pareto-optimal level, whichever comes first – but not beyond. Thus if $\bar{\tau} < s^*$, $\tau = \bar{\tau}$ and firm-specific investments fills up the remainder such that $\tau + s = s^*$, but s is otherwise zero.

In the situation at which $(1-q)\Delta$ falls short of $c(s^*)$, the equilibrium contract impedes general training to the extent that τ falls short of s^*. As a consequence, $s = s^* - \tau$. Interestingly, general training in the presence of firm-specific human capital exceeds that of its absence. To appreciate this, notice that $(1-q)\Delta < c(s^*)$ implies $(1-q)\Delta < c(\tau^*)$, and that training in the absence of general human capital thus solves $(1-q)f(\tau) - (1-q)\Delta = (1-q)f(\tau) - c(\tau)$. However, as $(1-q)f(s^*) - c(s^*) > (1-q)f(\tau) - c(\tau)$, the result follows. The reason is of course that a positive level of firm-specific human capital imposes an additional wedge between a worker's marginal product and her outside option. As a consequence, the renegotiation point, $\bar{\tau}$, is higher, leaving additional room for training in general skills. Therefore, as a final remark, it ought to be noted that as an immediate corollary, general training is positive *even* in the case in which Δ is zero.

Whenever $(1-q)\Delta$ falls between the larger $c(\tau^*)$ and $c(s^*)$, the equilibrium contract permits a sufficiently large renegotiation point such that $\tau \geq s^*$. As a consequence, general training coincides with the situation in which firm-specific training is absent, and s equals zero.

Lastly, when $(1-q)\Delta$ exceeds $c(\tau^*)$, the equilibrium contract again permits a sufficiently large renegotiation point to the extent that $\tau = \tau^*$. As a consequence, investments in both general- and firm-specific human capital coincides with the social optimum.

3.3. **Tuition Reimbursement Programs.** Firm-sponsored tuition reimbursement programs offer financial assistance to employees wishing to undertake coursework in order to improve their skill-set. Training is usually implemented at accredited academic institutions, casting little doubt on the generality of acquired skills. However, participation in most programs are also subjected to repayment clauses, which stipulate reimbursement of incurred training-costs were the worker to separate before some pre-specified minimum service period. Tuition reimbursement programs have experience a surge in popularity in recent years, and are estimated to be offered by as much as 85% of US firms (Manchester, 2007; Capelli, 2004). Despite this, there are no – at least not to the author's knowledge – theoretical studies investigating the implications of such programs on human capital accumulation.

As most provided training is of a general character, it is quite straightforward to incorporate the ideas of tuition reimbursement programs into the present framework. Most notably, repayment clauses dictate that in case of separation the worker incurrs cost $c(\tau)$, which then accrues to the employer. However, while court-cases reveal that repayment clauses can be, and commonly are, legitimately enforced, it is unclear whether this applies only to voluntary quits or also includes the situation of exogenous separations (see Kraus (2008), Section 5, for a detailed discussion of a number judicial precedents).[30] I will therefore consider both aspects.

Under the hypothesis of a legally enforceable repayment clause, a worker's outside option is given by

$$v(\tau) = f(\tau) - (1-\beta)k - c(\tau) - \Delta \tag{12}$$

In accordance with the definition in Acemoglu and Pischke (1999a), as $f'(\tau) > v'(\tau)$ the external wage-structure is compressed. Following a Nash-bargaining protocol, it is also easy to see that $w(\tau) = v(\tau) + \alpha\Delta$, where α is the worker's bargaining power and Δ the surplus of the relationship. As a consequence, the internal wage structure is also compressed. Yet, firm-sponsored training does not emerge naturally. To see this, appropriately modifying equation (2) in Acemoglu and Pischke (1999a) to incorporate the ideas of a tuition reimbursement program yields

$$(1-q)c'(\tau) = c'(\tau)$$

where it is assumed that repayment only occurs at voluntary separation. Clearly, optimal training equals zero.

On the other hand, however, if repayment also occurs at exogenous separations, the associated first-order condition is instead

$$(1-q)c'(\tau) + qc'(\tau) = c'(\tau)$$

and training is indeterminate. The reason behind these results are not far-fetched. With tuition reimbursement programs, the previously sunk-cost of training is instead intertemporally shifted and levied on the worker in case of separation. As this affects bargaining, the worker will not only receive all benefits associated training, but also, through a reduction in (future) pay, bear all of its costs. Thus, if repayment occurs in all states of the world, the firm is left indifferent between training a worker or not. However if, on the other hand, repayment is conditional on voluntary quits only, the firm will, in expectation, bear some

[30]For instance, Kraus (2008) states: "Several decisions have held that agreements by an employee to repay training costs, if the employee leaves before a specified period, do not alter either the company's right to discharge the employee at will, or the employee's obligation to repay after such a termination." Yet, in another case a pilot whose aircraft was taken out of service for prolonged maintenance left for another employer. The court concluded that his departure was a "constructive discharge" excusing any ongoing obligation to repay the costs of training.

of the cost, but reap none of the rewards. As a consequence, optimal training, in this case, is zero.

To economize on notation, let d be an indicator variable assuming $d = 1$ if repayment occurs at exogenous separations, and $d = 0$ if not. Conditional on having entered the market, a training-firm's problem under a tuition reimbursement program is given by

$$\pi(V) = \max_{w,\tau \geq 0} \{(1-q)(f(\tau) - w + \beta k) - c(\tau) + q(k + dc(\tau))\} \tag{13}$$

$$\text{s.t.} \quad V \leq (1-q)w + q(f(\tau) - dc(\tau) - (1-\beta)k - \Delta) \tag{14}$$

$$w \geq f(\tau) - c(\tau) - (1-\beta)k - \Delta \tag{15}$$

We then have the following results.

Proposition 5. *If $d = 0$ there exist a unique equilibrium with training*

(i) $c(\tau) = \frac{(1-q)}{q}\Delta$, *if* $c(\tau^*) \geq \frac{(1-q)}{q}\Delta$,
(ii) $\tau = \tau^*$, *if* $c(\tau^*) \leq \frac{(1-q)}{q}\Delta$,
(iii) and $\tau = \tau^*$ *if* $q = 0$, *for all* $\Delta \geq 0$.

Proof. In Appendix A. □

Proposition 6. *If $d = 1$ there exist a unique equilibrium with training*

(i) $\tau = \tau^*$, *for all* $\Delta > 0$.
(ii) For $\Delta = 0$ *there are multiple equilibria with* $\tau \in [0, \tau^*]$.

Proof. In Appendix A. □

The intuition underlying Proposition 5 is straightforward. The repayment clause effectively reduces a worker's outside option by $c(\tau)$. As a consequence, a firm's ex post quasi-rent must, at a maximum, equal $c(\tau) + \Delta$. In equilibrium, ex ante costs coincide with *expected* ex post quasi-rents, and $c(\tau) \leq (1-q)(c(\tau)+\Delta)$.[31] Therefore, either training solves $c(\tau) = \frac{(1-q)}{q}\Delta$ – and renegotiation is imminent – or training reaches the social optimum, at which $c(\tau^*) \leq \frac{(1-q)}{q}\Delta$.

In contrast to Proposition 5, however, Proposition 6 merits a deeper discussion. Following the intuition of Proposition 1, when renegotiation is not a binding concern the firm's objective function is strictly increasing on $\tau \in [0, \tau^*)$. As a consequence a firm will unambiguously train up until $\min\{\bar{\tau}, \tau^*\}$. In marked difference to the previous logic, however, whenever renegotiations are imminent, the optimal level of training is instead indeterminate. To appreciate this, substituting the poaching constraint (15) into the firm's objective

[31] With equality if and only if renegotiation is imminent.

function yields

$$\pi(V) = k + (1-q)\Delta \tag{16}$$

which is independent of training. The reason is that workers, and not firms, are not only the sole residual claimant to any marginal benefits, but also assume all marginal costs. The firm's marginal gain to training is nil.

Nonetheless, whenever Δ is strictly positive, equation (16) also reveals that profits exceed k, suggesting that renegotiation can never be a concern in equilibrium. The equilibrium contract must therefore assume a sufficiently generous value, assuring that training reaches the social optimum and that renegotiations are far from impending.

In contrast to this reasoning, however, if Δ instead equals zero, profits equal k *at any level of training*.[32] Thus, while contract $V = f(0) - (1-\beta)k$, for instance, is an equilibrium contract with associated training $\tau = 0$, so is contract $V = f(\tau^*) - c(\tau^*) - (1-\beta)k$ with training τ^*. The entire set of possible equilibria is therefore straightforwardly given by $V = f(\tau) - c(\tau) - (1-\beta)k$, with $\tau \in [0, \tau^*]$.

Despite this tremendous degree of multiplicity, some equilibria appear more reasonable than others. In particular, suppose that V is a specific equilibrium outcome with associated training $\tau < \tau^*$. Then there is nothing which prevents an individual firm from offering a contract $\hat{V} > V$ with associated training $\hat{\tau} > \tau$. Profits, of course are left unaltered.[33] As a consequence, I find it difficult to imagine reasons as to why an individual firm and worker could not agree on such an obvious Pareto-improving policy, leaving the social optimum, in fact, the only reasonable and therefore uniquely determined equilibrium.

Admittedly, however, the contract in Proposition 6 is quite elaborate. Not only does it stipulate a specific wage, but also a certain training level as well as repayment clauses detailing monetary transactions in case of separation. Yet, most tuition reimbursement programs are of a voluntary nature and made readily available to all employees, including past hires. Quite surprisingly, however, the results in Proposition 6 do not hinge on the contractibility of training. To appreciate this, recall from the discussion in Section 3.1 that wage-contracts alone fail to internalize the separation externality, impeding training beyond the constrained efficient level, $\hat{\tau}^*$. More precisely, the separation externality instills a wedge between the private and social returns to training, compelling equilibrium training to, at the very most, satisfy $(1-q)f'(\hat{\tau}^*) = c'(\hat{\tau}^*)$. However, while the separation externality bounds marginal returns to not exceed $(1-q)f'(\tau)$, the repayment clause bounds marginal

[32]Provided that renegotiations are imminent, which they are as the optimal τ equals $\bar{\tau}$ for a sufficiently tight V.

[33]Notice, though, that the reverse is not true: No individual firm may offer some contract $\hat{V} < V$ and still remain in business.

costs not to exceed $(1-q)c'(\tau)$. As a consequence, in the absence of renegotiation – and, more importantly, *in the absence of contractible human capital investments* – a firm's first order condition with respect to training observes $(1-q)f'(\tau) = (1-q)c'(\tau)$, ensuring a socially desirable outcome. These ideas are summarized in Corollary 1 below.

Corollary 1. *Suppose that a contract, V, takes the form of a wage. Then the results in Proposition 6 are unaltered.*

Proof. In Appendix A. □

4. Discussion

The model analyzed in the preceding sections provides a novel view on firms' incentives to invest in training. However, while the interactions that underpin the main mechanisms are original to this study, the individual components are, to a large extent, not. It therefore appears appropriate to discuss the implications of the model's main building-blocks, and to relate them to the relevant theoretical literature. In addition, empirical predictions are discussed and put in context with existing applied work. The main equilibrium implications, I argue, are largely supported by the data.

4.1. **Theoretical literature.** A hold-up problem arises when parts – or all – of the returns on an agent's relation-specific investments are ex post expropriable by her trading partner. More precisely, when ex ante costs are entirely absorbed by the investing party and when contractual incompleteness infer ex post bargaining over gross returns, investments are typically left inefficiently low (Grout, 1984; Williamson, 1975). The ideas underpinning a hold-up are intimately related to those of firm-sponsored investments in human capital: Firms devote time and resources towards employee training, absorbing the entire associated cost. As training expenses are sunk at later stages of the production process, ex post bargaining falls short of efficiently assigning residual rents, and training therefore falls well below the social optimum.

When training is of a general character, however, the problem of a hold-up is further exacerbated. As the accumulation of skills is vested in the worker, and not the firm, any resulting improvement of a worker's marginal product is immediately, and in equal proportion, reflected in her outside option. As a consequence, ex post – or gross – surplus is left unaffected, leaving the firm bearing *all* associated costs, but reaping *none* of the associated rewards. Indeed, the Beckarian poaching externality is thoroughly isomorphic to this exasperated version of the hold-up problem.

The theoretical literature on hold-ups has suggested several ingenious and empirically relevant solutions to the problem. Notably, Klein, Crawford, and Alchian (1978) and Grossman and Hart (1986) argue that the problem of hold-ups may explain the emergence of vertical integrations, and ultimately substantiate a theory of the firm (Williamson, 1985). Legal considerations, such as at-will employment, however, prevents analogous organizational solutions within firm-worker relationships, and can therefore not comprise the foundation of a theory of firm-sponsored investments in general training.[34]

Another prominent solution suggested in the literature is the use of fixed price contracts (Chung, 1991; Edlin and Reichelstein, 1996). Whereas the murky nature of investments may obstruct enforcement of complete contracts assigning residual rents in all states of the world, a simpler contract which stipulates a fixed transaction-price appears a more unassuming premise.[35] The mechanism is quite intuitive. When investments improves the valuation of a good to one of the participating agents, a fixed price of transaction ensures that all residual rents will accrue to the very same party.[36] Thus, absent renegotiations, a firm investing in a worker's skills under this assertion will therefore reap the full residual benefits, leading to an efficient allocation of human capital.

Despite these lucid arguments, however, the general nature of human capital adds some additional layers of complexity to the analysis. Most importantly, as investment in general skills not only improves a worker's marginal product, but also her attractiveness to competing employers, renegotiations may naturally emerge. Given a certain contract, this is a particularly acute concern if a worker wishes to exercise her right to terminate the employment relation. As a consequence, a theory of firm-sponsored training is incomplete without the addition of an integrated theory of renegotiations. And as previously argued, renegotiations by mutual consent provides a plausible departure point in order to characterize the process of reformulating previously agreed contracts (MacLeod and Malcomson, 1993).

While fixed price contracts can largely circumvent the issues concerning hold-ups, the looming threat of renegotiations in the current setting may well bring the problem back at full force. Thus, the mere *level* of prices, which largely governs the point of renegotiations, turn into an integral part of the analysis. To this end, I have considered a competitive

[34]In a related study Hart and Moore (1990) show how the allocation of asset-ownership may mitigate, and even circumvent, the problem of hold-ups. However as the "asset" is defined the object to which investments are directed, and "asset-ownership" as the legal right to put that asset into use elsewhere, an analogous solution is not applicable in the case of employee training.

[35]Implicitly, the use fixed price contracts presumes that trade is observable by a third-party enforcer (e.g. courts of law).

[36]This type of investments is usually referred to as "self-investments". See Che and Hausch (1999) for detailed discussion of "cooperative investments".

equilibrium in which resulting prices direct the entry of firms in order to clear the labor market.

As a final remark, it should be noted that this is not the first study to analyze the implications of equilibrium conditions on contracting. Cooley, Marimon, and Quadrini (2004), Phelan (1995), and Krueger and Uhlig (2006) all consider a framework of risk-sharing with (one-sided) limited commitment in which there is a large market of potential outside partners. As here, the competitive aspects of the economy shapes the provision of contracts, and ultimately the allocation of resources. There are, however, some substantial differences. Most notably, in risk-sharing economies insurance is, by assumption, something mutually beneficial. The question is rather how much risk-sharing can be sustained in a competitive environment with limited enforcement. In contrast, this paper focusses on the provision of training which may, or may not, be mutually beneficial. In particular, fixed-price contracts shifts potential residual returns from the worker to the firm, encouraging investments in general skills. However, as renegotiations are imminent, residual claims are instead redirected to the worker, and training comes to an abrupt halt. The competitive nature of the labor market determines the precise level of contracts, renegotiations, and ultimately determines the level of training.

4.2. **Empirical relevance.** While the empirical literature on firm-sponsored training is large, there are several econometric concerns that limit the scope to accurately identify causal mechanisms. Human capital is, almost by definition, unobservable; data on worker productivity is scarce and sometimes unobtainable; rejected outside offers are rarely recorded; mobility costs are plausibly worker-specific or may well be intertwined with alternative match-specific components such as firm-specific human capital; and the decision to invest – or to accept training – is almost surely endogenous and depends on the employer's perception of several industry-, firm-, or worker-characteristics which may well be unobserved to the econometrician. As a consequence, the empirical literature is largely constrained to confine attention towards equilibrium characterizations in order to disentangle which theory is more or less consistent with that observed in the data.

Under the hypotheses laid out in this study, equilibrium training ought to be intimately and positively related to both mobility-costs, Δ, and to the retention-rate, $1-q$ (see Proposition 1). Indeed, using establishment-level data in the United States, Frazis, Gittleman, and Joyce (2000) find turnover to have a negative effect on some (but not all) of their measures of training. Booth, Francesconi, and Zoega (1999) show that the higher the average quit rate in a British industry, the less likely is a full-time male employed in the industry to receive general training, and the fewer are the training days, if trained.

In addition, Muehlemann and Wolter (forthcoming) find that Swiss firms are less likely to provide apprenticeship training in dense regional labor markets, where the probability that workers are poached by other firms is higher. Brunello and Gambarotto (2007) find that in the United Kingdom, firm-sponsored training is less frequent in areas with higher local employment density, and Brunello and Paola (2008) provide further corroborating evidence for the case of Italy. In their seminal paper, Harhoff and Kane (1995) use data from the Mannheim Innovation Panel and show that firms are more willing to offer firm-sponsored training when there are only a few firms geographically around to poach their apprentices. Lastly, van Ours and Picchio (forthcoming) find that a decrease in labor market frictions significantly reduces firms' training expenditures in the Netherlands.[37]

A further commonly explored equilibrium implication deriving from theoretical models of training concerns the resulting wage structure. More precisely, a worker's *tenure premium* is defined as the additional wage increase that workers staying with their initial employers receive compared to those who leave. While the premium is *positive* under the hypothesis laid out in Acemoglu and Pischke (1998, 1999a), it is like to be *negative* under the current setting.[38] To see this, assume that Δ is comprised by two components $\Delta_m + \Delta_f$. The component Δ_m refers to a direct cost to the worker of relocating, while Δ_f denotes some firm- or match-specific component to productivity. The tenure premium is then given by

$$TP = \Delta_f - \frac{c(\tau)}{1-q} \tag{17}$$

Thus, following Proposition 1, if $c(\tau^*)$ weakly exceeds expected rents, $(1-q)\Delta$, the tenure premium equals the negative of Δ_m which, under quite plausible assumptions, is positive, rendering a negative tenure premium. However, whenever $c(\tau^*)$ falls short of $(1-q)\Delta$ the tenure premium may instead be positive depending on the relative magnitude of Δ_m and Δ_f. But a likely negative value appears a reasonable departure point.

In their study on the German apprenticeship system, Harhoff and Kane (1995) conclude that workers who remain with the training firm earn less than those who leave, suggesting that the tenure premium for previously trained workers indeed is negative. Clark (2001) construct a rich longitudinal data set which allows for a comparison between quits and layoffs among German apprentices, and confirm the prior results by Harhoff and Kane (1995). Using recent training data from the British Household Panel Survey, Booth and Bryan (2005) conclude that employer financed training raises wages both at present-, but foremost at future employers, and that the effect is the largest for training conducted at

[37] van Ours and Picchio (forthcoming) define labor market frictions as an index on the unit interval combining job-destruction and job-finding rates.

[38] Acemoglu and Pischke (1999a) pp. 549-550.

accredited institutions.[39] Finally, and as mentioned in the introduction, Loewenstein and Spletzer (1998) find similar results in the United States, Goux and Maurin (2000) in France, and Gerfin (2004) in Switzerland.[40] Moreover, in an interesting test of sensitivity, Gerfin (2004) finds that the negative tenure premium is further augmented when small firms are left out of the sample. While the mechanism behind this result is largely unknown, Gerfin hypothesize that large firms are more credible in offering long-term contracts and may extract rents from previously trained worker by paying a wage below marginal product.

4.3. **Policy Implications.** With respect to public policy, the ideas hypothesized in this paper support markedly different actions than those from previous studies. To see this, notice that as the main mechanism underlying a theory of *wage-compression* concerns *marginal* gains versus marginal costs, only marginal remedies are viable policy options. As a consequence, non-contractible subsidies have no effect on the provision of training, and translate instead to a direct windfall gain to targeted firms (Acemoglu and Pischke, 1999b). Consequently, Acemoglu and Pischke suggest regulation of training as a prioritized objective, as it would not only facilitate contractual arrangements between subsidies and training, but also remove the credibility issues surrounding training between the worker and the firm.[41] While regulation would indeed facilitate contractual performance between the worker and the firm in the present setting (cf. Propositions 1, 2 and 3), it is by no means necessary from a policy point of view. Indeed, a lump-sum subsidy directed towards a training-firm, or a lump-sum tax levied on non-training firms, would induce an identical outcome to that of a larger match-specific component, Δ. These ideas are summarized in Proposition 7.

Proposition 7. *A socially optimal level of training, τ^*, can be attained by a lump-sum (non-contractable) subsidy to training-firms, or by a lump-sum tax levied on non-training firms.*

Proof. In Appendix A. □

[39]Indeed, Booth and Bryan (2005) argue that their results are consistent with a situation in which firms offer credit constrained workers training which is then "repaid" through wages below the worker's marginal product at later stages of the relationship.

[40]In sharp contrast, however, Acemoglu and Pischke (1998) find that only exogenous "quitters" (due to mandatory military service) have a negative tenure premium, while it is positive for workers who quit for endogenous reasons. Nevertheless, the estimated positive tenure premium is not very precise, and is not statistically different from zero.

[41]Acemoglu and Pischke (1999a) argue that contractable training may induce workers to accept a wage-concession early in the employment relation, and therefore (indirectly) finance their own investment in general human capital.

The arguments underlying Proposition 7 are quite intuitive in light of the previous analysis. Given a certain contract, V, an unconditional subsidy unambiguously improves a training-firm's profits to exceed k. As a consequence, market forces put upward pressure on the price of labor, leaving additional room for training absent the imminent threat of renegotiations. As the increase in training improves workers' productivity further, profits again exceed k, putting additional pressure on wages, leaving even more room for training, and so on. The final effect on equilibrium human capital acquisition may straightforwardly be visualized in Figure 2: A training subsidy yields an upward shift of equal magnitude in the parabola tracing out the zero-profit condition. Obviously, at a sufficiently large subsidy, the new equilibrium level of training must correspond to the social optimum. With respect to taxes on non-training firms, on the other hand, the equilibrium can instead be visualized as an outward shift of the monotonically increasing renegotiation-curve. The final effect is, of course, qualitatively similar

Arguably, considering the intangible nature of training, the presence of non-contractable subsidies appears a more realistic *de facto* working hypothesis, and the ideas underpinning Proposition 7 indeed find some support in the data. Holzer et al. (1993) investigate whether training grants under the Michigan Job Opportunity Bank-Upgrade actually increase firm-provided training, or if they merely translate to a windfall gain to firms already providing some training. While perhaps indicative at most, they find that grants substantially, but temporarily, increase firms' training provisions, have a long lasting positive effect on workers' productivity, and does not constitute a mere windfall benefit to training firms.

5. Conclusions

This paper has studied a model of firm-sponsored investments in general human capital in which firms' ability to credibly offer long-term contracts and the competitive nature of markets play a pivotal role in shaping the provision of training. As contracts are renegotiated by mutual consent, firms' quasi-rents are increasing in training, providing solid incentives for firms to finance investments in workers' general skills. The competitive nature of markets ensure that firms do not earn excess profits, disciplining contracts to equate ex post quasi-rents with ex ante costs. As rents intimately relate to any match-specific component of productivity – e.g. firm-specific human capital, or mobility costs – so does the equilibrium level of training. As a consequence, equilibrium investments in general skills stand in direct parity to the money metric extent of which worker's are tied to their current employer, or more simply; to their mobility cost.

The model infers a number of verifiable, and often verified, predictions. Consistent with several empirical studies – and common to other theories on firm-sponsored training – observed investments in human capital ought to be negatively related to turnover, as separations impair future profits which themselves pertain to training. Perhaps more interestingly, however, the model suggests that training should intimately relate to *any* component which permit firms to extract quasi-rents from their employees.[42] Indeed, several empirical studies document that investments in general human capital appears to be more generous, and more frequent, in areas where the geographical density of competing employers is low.

From a policy perspective, the present study yields some novel insights. In particular, the elusive nature of human capital often deems training a non-contractible investment. As a consequence, previous theoretical studies have cast some doubt on the usefulness of government subsidies, as these are unlikely to improve the *marginal* rewards to training. In contrast, the arguments put forward in this paper suggests that even grants of a lump-sum nature may well improve the allocation of human capital, as they increase ex post profits and ultimately the provision of training.

[42]It should be noted that this prediction stands in marked contrast to competing theories, in which *only* components that *correlate* with training are suggested to effect the allocation of human capital.

Appendix A. Proofs

A.1. **Proof of Proposition 2.** Conditional on a certain choice of τ, a necessary and sufficient condition for optimal wage-setting is given by

$$w = \max\{V, f(\tau) - (1-\beta)k - \Delta\}$$

As a consequence, the objective function is strictly increasing on $\tau \in [0, \min\{\bar{\tau}, \hat{\tau}^*\})$ – where $\bar{\tau}$ is defined as $V = f(\bar{\tau}) - (1-\beta)k - \Delta$, and $\hat{\tau}^*$ solves (8) – and strictly decreasing thereafter. Optimal training is therefore given by $\min\{\bar{\tau}, \hat{\tau}^*\}$. Optimal wage-setting combined with the optimal choice of training reveals that wages satisfy $w = V$.

In equilibrium, however, firms make profits k, and V must therefore satisfy

$$V = f(\tau) - (1-\beta)k - \frac{c(\tau)}{1-q} \tag{A1}$$

Inserting the equilibrium V into the wage-setting equation yields

$$w = \max\{f(\tau) - (1-\beta)k - \frac{c(\tau)}{1-q}, f(\tau) - (1-\beta)k - \Delta\}$$

Combining the equation above with the optimal choice of training implies that if $c(\hat{\tau}^*) \geq (1-q)\Delta$, the unique equilibrium is given by $c(\tau) = (1-q)\Delta$. And if $c(\hat{\tau}^*) \leq (1-q)\Delta$, the unique equilibrium is given by $\tau = \hat{\tau}^*$.

A.2. **Proof of Proposition 3.** A non-defecting firm's total profits are given by

$$k = \frac{1}{1-\beta}\left(f(\tau) - c(\tau) - q\Delta - V\right) \tag{A2}$$

where τ simply refers to a firm's equilibrium training level, and V the equilibrium contract.

A *defected firm* has lost her reputation of committing to training. She must therefore pay wages $\hat{w}$ which are given by

$$(1-q)\hat{w} = V - q(f(\hat{\tau}) - (1-\beta)k - \Delta) \geq (1-q)w \tag{A3}$$

where $\hat{\tau}$ refers to the firm's optimal training level, *given that no other firm has defected.* The training level $\hat{\tau}$ coincides with the results in Proposition 2. It should therefore be noted that if $c(\hat{\tau}^*) \geq (1-q)\Delta$, a defecting firm behaves no differently from a non-defecting firm, and reputations are redundant. Thus the relevant scenario to have in mind is given by the situation at which $c(\hat{\tau}^*) \leq (1-q)\Delta$, and $\hat{\tau} = \hat{\tau}^*$. As a consequence, the inequality in (A3) is strict if and only if $\tau \neq \hat{\tau}$.

In addition, if a defected firm were to exogenously separate, her profits are given by $(1-\beta)k + \beta\hat{k}$, where $\hat{k}$ refers to her continuation profits. A defected firm's total profits are therefore given by

$$\hat{k} = \frac{1}{1-\beta}\left(f(\hat{\tau}) - c(\hat{\tau}) - q\Delta - V\right) \tag{A4}$$

Combining equations (A2) and (A4) yields

$$k - \hat{k} = \frac{1}{1-\beta}\left(f(\tau) - f(\hat{\tau}) - (c(\tau) - c(\hat{\tau}))\right) \geq 0 \tag{A5}$$

with strict inequality if and only if $\tau \neq \hat{\tau}$.

The profits of a *defecting firm* is then given by

$$\hat{\hat{k}} = (1-q)f(\hat{\tau}) + qf(\tau) - c(\hat{\tau}) - q\Delta - V + \beta\hat{k}$$

Hence

$$k - \hat{\hat{k}} = (1-q)(f(\tau) - f(\hat{\tau})) - (c(\tau) - c(\hat{\tau})) + \beta(k - \hat{k})$$

Inserting (A5) yields

$$k - \hat{\hat{k}} = (1-q)(f(\tau) - f(\hat{\tau})) - (c(\tau) - c(\hat{\tau})) + \frac{\beta}{1-\beta}\left(f(\tau) - f(\hat{\tau}) - (c(\tau) - c(\hat{\tau}))\right)$$

Clearly, if $\tau \neq \hat{\tau}$ and $\beta \to 1$, $(k - \hat{\hat{k}}) \to \infty$, and the value of defecting approaches minus infinity.

A.3. **Proof of Proposition 4.** Conditional on a certain choice of τ, optimal wage-setting and investment in firm-specific human capital are given by

$$(1-q)w = \max\{V, f(\tau) - (1-\beta)k - \Delta\} - q(f(\tau) - (1-\beta)k - \Delta) \tag{A6}$$

$$s = \begin{cases} \operatorname{argmax}\{(1-q)f(s+\tau) - c(s+\tau)\} & \text{if } \tau \leq s^*; \\ 0 & \text{elsewhere.} \end{cases} \tag{A7}$$

The objective function of the firm is, again, strictly increasing in τ on $[0, \min\{\bar{\tau}, \tau^*\})$, and decreasing thereafter. Therefore, the optimal level of general training is given by $\tau = \min\{\bar{\tau}, \tau^*\}$.

An equilibrium contract must satisfy

$$V = qf(\tau) + (1-q)f(\tau+s) - c(\tau+s) - (1-\beta)k - q\Delta \tag{A8}$$

Inserting into the wage-setting equation yields

$$\begin{aligned}(1-q)w = \max\{&qf(\tau) + (1-q)f(\tau+s) - c(\tau+s) - (1-\beta)k - q\Delta, f(\tau) - (1-\beta)k - \Delta\} \\ &- q(f(\tau) - (1-\beta)k - \Delta) \end{aligned} \tag{A9}$$

First, it is important to notice that at $\tau = 0$, the left-hand side of the max operator exceeds the right-hand side, as $(1-q)f(s^*) - c(s^*) > (1-q)f(0)$.

If $(1-q)\Delta < c(s^*)$, the left- and the right-hand side has a unique crossing point given by $(1-q)f(\tau) - (1-q)\Delta = (1-q)f(s^*) - c(s^*)$, with $\tau < s^*$. As a consequence, $s = s^* - \tau$.

If $c(\tau^*) > (1-q)\Delta \geq c(s^*)$, the left- and the right-hand side of the max operator has a unique crossing point given by $c(\tau) = \Delta(1-q)$, with $\tau \geq s^*$. As a consequence, $s = 0$.

Lastly, if $c(\tau^*) \leq (1-q)\Delta$, there exist no crossing point for $\tau \leq \tau^*$, and investments in general training must therefore equal τ^*. As $\tau^* > s^*$, the optimal level of firm-specific human capital equals, again, zero.

A.4. **Proof of Proposition 5.** Rearranging constraint (14) under the hypothesis that $d = 0$ yields

$$(1-q)w \geq V - q(f(\tau) - (1-\beta)k - \Delta)$$

Conditional on a certain choice of τ, a necessary and sufficient condition for optimal wage-setting is therefore given by

$$(1-q)w = \max\{V, f(\tau) - (1-\beta)k - \Delta - (1-q)c(\tau)\} - q(f(\tau) - (1-\beta)k - \Delta) \tag{A10}$$

As a consequence, the objective function is strictly increasing on $\tau \in [0, \min\{\bar{\tau}, \tau^*\})$ – where $\bar{\tau}$ is defined as $V = f(\tau) - (1-\beta)k - \Delta - (1-q)c(\tau)$ – and strictly decreasing thereafter. Optimal training is therefore given by $\min\{\bar{\tau}, \tau^*\}$. Optimal wage-setting combined with the optimal choice of training reveals that wages satisfy

$$(1-q)w = V - q(f(\tau) - (1-\beta)k - \Delta)$$

In equilibrium, however, firms make profits k, and V must therefore satisfy

$$V = f(\tau) - (1-\beta)k - c(\tau) - q\Delta \tag{A11}$$

That is, as previously, the optimal level of training depends on the contract, V, and the equilibrium level of V depend on the optimal level of training.

Inserting the equilibrium V in equation (A11) into the wage-setting equation (A10) yields

$$\begin{aligned}(1-q)w = \max\{f(\tau) - (1-\beta)k - c(\tau) - q\Delta, f(\tau) - (1-\beta)k - \Delta - (1-q)c(\tau)\}\\ - q(f(\tau) - (1-\beta)k - \Delta)\end{aligned}$$

Combining the equation above with the optimal choice of training implies that if $c(\tau^*) \geq \frac{(1-q)}{q}\Delta$, the unique equilibrium is given by $c(\tau) = \frac{(1-q)}{q}\Delta$. And if $c(\tau^*) \leq \frac{(1-q)}{q}\Delta$, the unique equilibrium is given by $\tau = \tau^*$.

A.5. **Proof of Proposition 6.** Rearranging constraint (14) under the hypothesis that $d = 1$ yields

$$(1-q)w \geq V - q(f(\tau) - (1-\beta)k - \Delta - c(\tau))$$

Conditional on a certain choice of τ, a necessary and sufficient condition for optimal wage-setting is therefore given by

$$(1-q)w = \max\{V, f(\tau) - (1-\beta)k - \Delta - c(\tau)\} - q(f(\tau) - (1-\beta)k - \Delta - c(\tau)) \tag{A12}$$

As a consequence, the objective function is strictly increasing on $\tau \in [0, \min\{\bar{\tau}, \tau^*\})$ – where $\bar{\tau}$ is defined as $V = f(\tau) - (1-\beta)k - \Delta - c(\tau)$ –, flat until $\tau = \tau^*$, and decreasing thereafter. Optimal training is therefore given by the interval $[\bar{\tau}, \tau^*]$. Optimal wage-setting combined with the optimal choice of training reveals that wages satisfy

$$(1-q)w = V - q(f(\tau) - (1-\beta)k - \Delta - c(\tau))$$

In equilibrium, however, firms make profits k, and V must therefore satisfy

$$V = f(\tau) - (1-\beta)k - c(\tau) - q\Delta \tag{A13}$$

Inserting the equilibrium V in equation (A13) into the wage-setting equation (A12) yields

$$\begin{aligned}(1-q)w = \max\{f(\tau) - (1-\beta)k - c(\tau) - q\Delta, f(\tau) - (1-\beta)k - \Delta - c(\tau)\}\\ - q(f(\tau) - (1-\beta)k - \Delta)\end{aligned}$$

However, as $f(\tau) - (1-\beta)k - c(\tau) - q\Delta > f(\tau) - (1-\beta)k - \Delta - c(\tau)$ for any $\Delta > 0$, τ must always equal τ^* in equilibrium.

If $\Delta = 0$, there are multiple equilibria in which $\tau \in [0, \tau^*]$.

A.6. **Proof of Proposition 7.** The firm's optimization problem is now given by

$$\begin{aligned}\pi(V) = \max_{w,\tau\geq 0} &\{(1-q)(f(\tau) - w + b + \beta k) - c(\tau) + qk\}\\ \text{s.t.} \quad & V \leq (1-q)w + q(f(\tau) - (1-\beta)k - \Delta - t)\\ & w \geq f(\tau) - (1-\beta)k - \Delta - t\end{aligned}$$

where b is a subsidy given to a training firm while t is a tax imposed on a non-training firm. Repeating the same steps as in Proposition 1 reveals that the policy b and t must satisfy

$$(1-q)(\Delta + t + b) \geq c(\tau^*)$$

If the government is further assumed to run a balanced budget, we have

$$qt = (1-q)b$$

Thus, a tax, t, such that

$$t = c(\tau^*) - (1-q)\Delta$$

would induce Pareto-optimal training.

A.7. **Proof of Corollary 1.** If firms cannot commit to a value, optimal wage-setting yields

$$w = \max\{V, f(\tau) - (1-\beta)k - \Delta - c(\tau)\} \tag{A14}$$

The firm's objective function is therefore strictly increasing on $[0, \min\{\bar{\tau}, \tau^*\}]$ and decreasing thereafter.

In equilibrium firms make profits k, and V must therefore satisfy

$$V = f(\tau) - (1-\beta)k - c(\tau) \tag{A15}$$

Inserting the equilibrium V in equation (A15) into the wage-setting equation (A14) yields

$$w = \max\{f(\tau) - (1-\beta)k - c(\tau), f(\tau) - (1-\beta)k - \Delta - c(\tau)\}$$

Hence, if $\Delta > 0$, the unique equilibrium is given by $\tau = \tau^*$. If $\Delta = 0$, the equilibrium is indeterminate and $\tau \in [0, \tau^*]$.

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