Information and Human Capital Management*

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Abstract

Employees differ both in terms of general human capital and firm-specific human capital (or match with a particular firm). Current employers typically have access to more information about their employees than rival employers. This information asymmetry affects the distribution of wages, turnover rates, profits, and the extent of allocative inefficiency in the labour market. We begin by exploring the implications of different information structures and highlight that information affects both the extent and distribution of adverse selection. We then suppose that firms can affect the information that they or their rivals observe, thereby endogenizing the extent and nature of asymmetric information between current and rival employers. In particular, we highlight that different information structures that lead to similar adverse selection can differ in their allocative efficiency. Using this observation, we detail how optimal information management policies vary across firms with different human capital management priorities, and how these decisions affect aggregate labour market outcomes.

Keywords: human capital, information disclosure, regression to the mean, adverse selection, turnover, wage distribution, human resource management.

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1 Introduction

Two central and established themes in labour theory are adverse selection and the distinction between firm-specific and general human capital. However, typically, these themes have been considered separately. This paper begins by introducing match-specific value in a standard model of adverse selection, building on a large literature initiated by Waldman (1984) and Greenwald (1986). Specifically, rival employers observe some statistic about a worker's productivity and make wage offers. Having observed these offers, the current employer decides whether to retain the worker (matching the highest outside offer) or to release her.

Allowing for firm-specific matches introduces a regression to the mean effect in the model. This arises because the current employer's best estimates—based on her private information—of a worker's productivity if retained within the firm (*retained* human capital) and if released to join another firm (*general* human capital) are not perfectly correlated: sometimes workers will be expected to be more productive if retained and sometimes more productive if released. In this context, regression to the mean implies that workers with high retained productivity are likely to have lower productivity elsewhere, conversely workers with low retained productivity in their first employment are expected to have higher productivity elsewhere. This provides a reason for some workers to switch jobs purely on the grounds of efficiency. A contribution of the paper is to explore how this 'legitimate' reason for job turnover interacts with the other fundamental force, adverse selection, under different information structures (that is, assumptions about the information held by current and rival employers).

In characterising the effect of an information structure, it is useful to focus on the extent of adverse selection that arises when outside employers draw inferences from the current employer's retention decision. When outside firms have information that eliminates the need to make this inference there is no adverse selection. For example, this will be the case is outside employers have the same information as the current employer about a worker's outside productivity (or general human capital). Equally, if the outside employers have the same estimate as the current employer of inside productivity, then public information is finer than that contained in the retention decision, so once again there is no adverse selection. Note, however, that while these two information structures or regimes induce the same adverse selection (and hence the same expected wage), they differ in their efficiency in allocating labour.

More generally, in assessing different information structures, we define the quantity of adverse selection at each realisation of the statistic observed by outside firms as the difference between the wage if there were no private information and its equilibrium value. In Section 3.3, in our joint normal specification of the model, we show that information structures consisting of a garbled report of the current employer's best estimate of outside productivity (i.e. general human capital plus random noise) generate an amount of adverse selection that is independent of the realisation. However, we identify other information structures for which adverse selection is imposed more heavily on those workers whom it is efficient for the firm to retain.[1] Our goal is to analyze the impact of different information structures on average wages, firm profits and retention decisions.

For application, it is important to consider how different information structures might arise. First, it is natural that the nature of production, or the industry might lead to exogenously different information structures. Trivial, but illustrative examples, include that the information available to potential employers about sportsmen, actors, and musicians is quite different to the information on private investigators, or spies. Similarly, the information about programmers that outsiders observe can differ dramatically depending on whether the project is open source or closed source (as discussed for example in Lerner and Tirole (2005), Spiegel (2005), and in an approach perhaps closest to this paper, Blatter and Niedermayer (2008)).

Further, varied information structures might arise endogenously through firms' decisions. Specifically, we analyze firms' strategic choices when they commit to the information available to potential rival employers. For example, firms might credibly commit (either contractually, or often through reputational concerns) as to how much time a programmer can spend on open source, or the extent to which a consultant or lawyer has direct access and contact with clients, publicize that the worker is indeed employed at the firm, for example, through a website, or even institute rules and restrictions on social interactions (Leibeskind, 1997). More broadly, choices over production technologies (such as whether to require team or solo production) and the design of organization (including layers of hierarchy and promotion criteria) will affect the information structure. Here, we abstract from considering direct costs in such choices and, instead, treat the firm as directly choosing the nature of the signal observed by rival potential employers.

Using our characterization of the effects of different information structures, it is relatively straightforward to characterize firm's preferred information policies. Our results here are driven by a simple trade-off: policies that best enable firms to exploit talent (by capturing general human capital rents) make it hard to attract employees, and vice versa. Equilibrium policies therefore reflect the relative importance to the firm

[1] In the language of auction theory, bidders observe a combination of common and private valuations, rather than, e.g., a garbling of the common valuation.

of attracting versus exploiting talent.

To explore these ideas, we extend the model by supposing that firms compete to hire workers in each of two periods. In the first stage, no firm holds an informational advantage. Firms can gain informational advantage through first period employment and depending on initial contracts which consist not only of a wage offer, but, also, a disclosure policy (leading to a particular information structure). Having chosen a first period employer, workers generate performance statistics which are privately observed by their employer, as well as acquiring skills that are valuable in second period production. The second period then proceeds exactly as above, outside firms observe some statistic of this information (arising from the disclosure policy to which the first period employer had committed) and then make second period wage offers. Having observed these offers, first period employers decide whether to retain their workers (matching the highest outside offer) or to release them. Workers then engage in second period production and the game ends.

Note that in the first period competition between firms, firms attract workers both directly, through first period wages, and indirectly, through the future careers (as expressed by the expected second period wages) that they offer. These career prospects, in turn, arise from the general skills and training that are offered in the firm (which, for the most part, we treat as exogenous) and from the disclosure policy chosen. Disclosure policies, however, do not simply imply transfers of second period surplus between employees and first period employers, since different disclosure policies vary in the extent of surplus-destroying allocative distortion that they introduce. We can quantify this explicitly using our characterization of information structures that associates with each possible disclosure policy a pair of outcomes: expected future earnings for the worker and expected future profits for the firm.

Thus the disclosure policy for our firms corresponds to the best choice from the set of feasible wage, profit pairs, bearing in mind that first period wages can transfer future profit to workers but, because of credit constraints, not necessarily future wages to profit. Firms facing competition to attract workers (*competitive firms*) will seek to maximise efficiency (the sum of future earnings and future profits which are transferred to the worker as current wages). In contrast, 'technologically advantaged' firms face limited competition and transform worker rent into profits via adverse selection (*skill-augmenting firms*).

These results have implications for labour market outcomes.[2] In Section 5.2.1,

[2] Acemoglu (2002) stresses that technological changes are likely to alter the ways in which firms organise production and consequently impact on labour market outcomes. The current paper endorses

we calculate how wage distributions and labour turnover rates respond, via information management policies, to technological changes in the skill-augmenting sector. A decline in either the mean of estimated general human capital formation or mean match quality, or an increase in the variance of estimated match quality, increases the rate of labour turnover in the skill-augmenting sector. Interestingly, since an increase in the variance of an estimate can be interpreted as an improvement in information, this suggests that observed increases in labour turnover could stem from improved information acquisition within 'innovative' firms. Turning to the distribution of wages, an increase in the "skill-gap" (the expected human capital difference between the skill-augmenting and competitive firms) increases inequality and skews the distribution of wage in the skill-augmenting sector to the left, while an increase in the mean, or a reduction in the variance, of estimated match quality increases inequality but has little impact on skewness.

Related Literature As noted above, our analysis draws on the familiar concepts of adverse selection and regression to the mean (the latter inducing match quality).[3] These concepts have been widely applied in the labour economics literature, although typically separately. The notion of match quality, building on Becker's distinction of specific human capital, was introduced by Jovanovic (1979) who shows that a non-degenerate distribution of worker-firm match values leads to worker turnover as information about match values accrues over time. In emphasising the dynamics of the learning process, Jovanovic abstracts from general human capital and (hence) adverse selection aspects. In contrast, Waldman (1984) and Greenwald (1986) focuses squarely on adverse selection, highlighting that this force can lead workers to earn less than their marginal products and has implications labour turnover.[4] Indeed, in Greenwald's model, there is no turnover unless there is a possibility that separations occur for exogenous reasons. We show that introducing a non-degenerate distribution of match quality into a model of general human capital formation counterbalances the forces of adverse selection. Even when firms hold

this view and details such a mechanism.

[3] Adverse selection can, of course, be traced back to Akerlof (1970). Regression to the mean predates even Galton (1885) who fixed the idea in what Koenker (2001) calls "Arguably, the most important statistical graphic ever produced." Galton's graphic related child and parental height. Tall parents tend to have tall children, though not so tall as themselves. Similarly for short parents. Of course, we are concerned with productivity in first and subsequent employments rather than heights of parents and children but the principal is the same.

[4] The fact that workers earn less than their marginal products gives rise to the possibility of firm-sponsored human capital investments. This idea is developed in many subsequent papers including Katz and Ziderman (1990), Chang and Wang (1996) and Acemoglu and Pischke (1998). Acemoglu and Pischke (1999) provide a review that emphasises the role of *exogenous* market frictions.

private information relating to general human capital (the Greenwald case), our model endogenously generates positive labour turnover.

In this sense, our paper is related to Li (2006) who also seeks to explain job mobility in the presence of asymmetric information over worker productivity. Li models the wage determination process as a first price auction. This creates a bidding situation similar to Milgrom and Weber's (1981) analysis of the 'mineral rights' model in which there is a single informed bidder and a number of uninformed bidders. In this setting, the uninformed bidders adopt a mixed strategy which generates positive turnover and a non-degenerate distribution of wages. Though in Li's setting there is no match-specific component of productivity and no efficiency consequences of turnover. In our model, wages are determined via a second price auction and turnover arises from the non-degenerate distribution of match quality. Notably, this gives an efficiency rationale for turnover that is absent in Li (2006). A further difference is that Li assumes the information structure to be exogenously fixed.

Eeckhout (2006) also studies a setting where current employers (exogenously) have superior information to outsiders to examine implications for turnover and wages. In his model there is gradual learning, as in Jovanovic (1979), but over general human capital rather than match quality. This approach contrasts with our model where information asymmetries are endogenous and there is persistence in match-specific values (the latter leads to our regression to the mean effect). A further difference arises in the wage-determination process. In Eeckhout's model wages are determined via a second price auction with two heterogenous bidders—an incumbent and a challenger, each of whom have private information (see, also, Pinkston 2008). In our model, wages are pinned down by the behaviour of (interim) identical outside firms. This "competitive fringe" assumption greatly simplifies the analysis.

Although we abstract from internal organisation costs of information management in order to focus on the adverse selection vs efficiency trade-off most directly, our paper relates to a significant organisational economics literature in which internal organisation costs play a major role. Waldman (1984) (and more recently DeVaro and Waldman (2005)), Ricart-i-Costa (1988) and Blanes i Vidal (2007) argue that, since adverse selection in the labor market can affect wages,[5] retention rates and thereby profits, firms will have incentives to distort (respectively) promotion, task assignment or delegation decisions. These are examples where organisational design is partly motivated by human

[5] Gibbons and Katz (1991) present empirical support for the economic significance of such effects. More recently, Schönberg (2007) finds evidence of adverse selection for college graduates, while Hu and Taber (2005) find a marked effect for white males. See also Kahn (2008). Finally, Pinkston (2008) presents evidence and discusses gradual asymmetric learning between different potential employers.

capital management issues and, furthermore, impacts through information flows to the labour market.[6]

Finally, our paper is also closely related to a growing literature studying information disclosure (see, e.g., Calzolari and Pavan (2006), Mukherjee (2008), Koch and Peyrache (2005) and Albano and Leaver (2005)). Like the current paper, this literature highlights that an employer's information management policy can form part of overall compensation as it influences an employee's future career prospects.[7] (See also Kim and Marschke (2005) and Lewis and Yao (2006) who explore this idea in the context of researchers). Though, many of these papers highlight career concern and moral hazard aspects omitted in our analysis; our paper focuses on the detailed implications for wages and turnovers of a broader range of information structures than is typically considered (for example, Albano and Leaver (2005) consider only fully transparent and fully opaque structures). Moreover, this paper in allowing for variation in both general human capital and match values, allows for consideration of efficient turnover and for richer information structure than many of these works which either force all workers to move firms between the first and second period (Koch and Peyrache, 2005) and Calzolari and Pavan, 2006) or assume that the worker is always more productive in the outside firm by a fixed amount (Mukherjee, 2008).

2 A Model of Information Structures and Labour Market Outcomes

Consider a current employer I who privately observes a vector-valued 'test statistic' Q_I. The vector Q_I should be thought of as everything the firm knows about its worker. In particular, information in Q_I will allow the current employer to estimate Y_{II}, the value of a worker's output when retained in firm I, and $Y_{II'}$ the value of her output when released to a different firm I'. It is convenient to think of the current employers information Q_I as simply given by Y_I the vector of productivities. This notation is somewhat cumbersome, but proves useful in the extension of the model in Section 4.

While the current employer, or inside firm, observes Q_I, rival employers observe a

[6] Burguet, Caminal and Matutes (1999) take a different path using similar ingredients. They argue that in certain industries, specifically professional sports, characterised by extreme visibility of performance, incentives are created for restrictive labour practices—such as transfer fees.

[7] Calzolari and Pavan (2006) allow for general disclosure policies, and do not have a labour market application specifically in mind. They do not consider the possibility of retention and assume a monopsonist employer in the second period, leading to somewhat different effects and considerations.

different statistic $T_I = T_I(Q_I)$. Note, we assume that inside firms always have available any relevant information that outside employers hold.[8]

Employment Wage Determination Outside firms compete to hire the worker and make "take it or lose it" employment wage offers. The employer then either matches the best offer made to the worker or releases this worker to join one of the highest outside bidders. Equivalently, there is an ascending open auction in which firms bid up wages until all but one firm drops out of the bidding.

As noted above, an alternative that does deliver somewhat different results is proposed by Li (2006). Li's first price auction model would appear to be appropriate in cases where final wage offers can be made by either side of the market, but not credibly communicated to the other side before the wage round must be concluded.

2.1 Simplifying Assumptions

In order to simplify the analysis of the employment wage determination process, we impose the following assumption on the joint distribution of test statistics and productivities.

Assumption 1. *For any pair of firms I' and I'', $(Q_I, Y_{II'})$ and $(Q_I, Y_{II''})$ have identical distributions.*

Outside firms are *interim identical*: they all take the same view of the worker's likely output in their firm (though the realizations in different firms may turn out to differ). Given this assumption, we can uniquely define

$$G_I \underset{def}{=} E[Y_{II'}|Q_I],\ I \neq I'.$$

The random variable G_I is the current employer's best estimate of the worker's value in an outside employment (her *general* human capital). Since the current employer holds all of the information relating to this worker in the economy, G_I is also the quantity that

[8] Note that, for a given information structure, all the information required to determine wages and retention decisions comprises the information held by rival employers T_I and the inside firm's best estimate of the worker's productivity in the firm $R_I = E[Y_{II}|Q_I]$. It follows, that while it is convenient to assume that the firm observes Q_I, there would be no loss in assuming that the firm observes only T_I and R_I. This lower information requirement for the incumbent firm might be a more palatable assumption and viewed as consistent with our maintained interpretation of the disclosed statistic T_I as arising through the firm's organizational design.

outside firms seek to estimate when making their employment wage offers. Similarly, we can define

$$R_I \underset{def}{=} E[Y_{II}|Q_I].$$

The random variable R_I is the first period employer's best estimate of the worker's value in the current, inside employment (her *retained* human capital).[9]

G_I will generally differ from R_I. Experience $Q_I = q$ may reveal that a worker fits especially well with firm I ($E[Y_{II}|Q_I = q] > E[Y_{II'}|Q_I = q]$) or, equally, that there has been a bad match. Differences between G_I and R_I will play an important role in our analysis, with the statistical possibility of a bad match *endogenously* generating labour turnover. It is natural to adopt a framework in which this matching manifests itself through regression to the mean: workers who perform well (badly) in their initial employment will tend to perform worse (better) if they switch jobs. This corresponds to an assumption that the regression 'line' $E[G_I|R_I = x]$ has a slope (derivative) everywhere between zero and one, implying, for instance, that $Cov(G_I, R_I) \geq 0$ and $Cov(R_I - G_I, R_I) \geq 0$. In fact, we will make a somewhat stronger assumption.

Assumption 2. *For each firm I, the pair of random variables $(R_I - G_I, G_I)$ are affiliated with density logconcave in each variable taken separately.*

This assumption leads to the following convenient properties, as proven in the Appendix.

Remark 1 Assumption 2 implies that, $E[G_I|R_I = r]$, $r - E[G_I|R_I = r]$,and $E[G_I|R_I - G_I = r]$ are all increasing in r. For any $w \in \mathbb{R}$, $E[G_I|R_I \leq w] \leq E[G_I]$ and $E[G_I|R_I \geq w] \geq E[G_I]$.

Regression to the mean introduces a "genuine reason for sale" which counterbalances the standard Akerlof lemons effect and tends to protect the market for experienced workers from complete collapse. Given regression to the mean, in the absence of any further information disclosure, an outside firm need not conclude that any worker it can hire at a given wage will generate a loss at that wage; rather, a released worker may simply have been a bad match. A further implication of regression to the mean is that efficiency in the allocation of labour requires a positive turnover of workers; to maximise productivity, a selection of workers *should* switch jobs.

[9] Our analysis allows Q_I to contain Y_{II} and $Y_{II'}$ but certainly does not rest on this assumption; all that is required is that firm I knows something about its worker's likely inside and outside productivity that other firms might not.

3 Analysis

3.1 Wage Determination and Definitions

With Assumption 1 in hand, characterising wages is relatively straightforward. Since outside employers are interim identical, employment wages will be set in Bertrand competition, and hence equal the expected productivity of a worker in an outside firm conditional on the publicly available information. This information includes the event that the worker is released by her current employer.[10] The equilibrium employment wage when a worker is employed by firm I and $T_I = T_I(Q_I) = t$ is realised is defined implicitly by

$$w_{T_I}(t) = E[G_I | T_I = t, R_I \leq w_{T_I}(t)], \tag{1}$$

whenever such a $w_{T_I}(t)$ exists.[11] The notation $w_{T_I}(t)$ denotes the wage payable under disclosure policy $T_I = T_I(Q_I)$ when $T_I = t$ is realised (we use T_I to denote both the disclosure policy and the random variable that it generates); $w_{T_I}(T_I)$ therefore denotes the random wage which will be generated by the disclosure policy. We will write the expected employment wage as

$$W_{T_I} = E[w_{T_I}(T_I)]. \tag{2}$$

The expected profit, is equal to output less employment wages in the event that the worker is retained (which occurs if the profits from doing so are positive), which we write as

$$\Pi_{T_I} = E[(R_I - w_{T_I}(T_I))^+], \tag{3}$$

where $(x)^+$ denotes x when positive, zero otherwise.

Next, we define the *degree of adverse selection* when $T_I = t$ is realised

$$AS_{T_I}(t) = E[G_I \mid T_I = t] - E[G_I \mid T_I = t, R_I \leq w_{T_I}(t)]. \tag{4}$$

The quantity $AS_{T_I}(t)$ measures how much lower the employment wage is when outside firms condition on the employer's retention behaviour in addition to the realisation $T_I =$

[10] The relevance of this event to employers bidding for G_I (common values) and the possibility of a winner's curse is familiar from auction theory.

[11] At this level of generality, we cannot rule out (perverse) cases where the implicit function theorem fails. In such cases, the equation does not define the function w_{T_I}; however, the condition is still required to hold. Also, it is possible that there is no w such that $w = E[G_I|T_I = t, R_I \leq w]$, in which case we set $w_{T_I}(t) = \inf \mathit{supp}\ G_I$.

t. Expected adverse selection equals the expected shortfall in employment wages from outside productivity,

$$E[AS_{T_I}(T_I)] = E[G_I] - W_{T_I}. \tag{5}$$

Finally, it is convenient to introduce notation for the feasible set, $\Omega(\Gamma_I)$. This set is the main object of our analysis and consists of the expected wage-profit pairs (W_{T_I}, Π_{T_I}) that can be achieved for a given set of disclosure policies, Γ_I.

We proceed in two stages. First, in Section 3.2, we establish some benchmark results under our general distributional assumptions for (G_I, R_I) but with a highly restricted set of information structures. Specifically, we focus on the case where $\Gamma_I = \{G_I, R_I, \varnothing_I\}$ in which outside firms observe the expected productivity of the worker G_I, the realised productivity of the worker in their current employment (more strictly, the estimate of future productivity within the firm), or simply nothing. Most of the related literature also restricts attention to these policies. Our analysis clarifies the forces at work and fixes some general features of the feasible set. Then, in Section 3.3, we specialise to the joint normal case. This allows us to explicitly trace through the impact of a rich set of alternative information structures on labour market outcomes.

3.2 General Distribution, Restricted Information Structures

3.2.1 Information Structures, $\Gamma_I = \{\boldsymbol{G}_I, \boldsymbol{R}_I, \varnothing_I\}$

Here we consider the following three more or less natural information structure.

1. G_I-disclosure, outside firms observe firm I's best estimate of the worker's general human capital: $T_I(Q_I) = E[Y_{JI}|Q_I] = G_I$.[12]

2. R_I-disclosure, outside firms observe firm I's of the worker's productivity if retained within the firm $T_I(Q_I) = E[Y_{II}|Q_I] = R_I$.

3. $\varnothing_I-$disclosure,[13] outside firms observe no additional information: $T_I(Q_I) = \varnothing_I$.

[12] Note that the same results would be achieved if outside firms observe all of the available information in the vector Q_I. Throughout we restrict our attention to outside firms observing scalar information statistics.

[13] We retain the subscript since, below, we allow for different types of current employer who may be more or less effective in transferring general human capital to the worker.

3.2.2 Wages and Profits

G_I-**disclosure**

$$w_{G_I}(G_I) = E[G_I|G_I, R_I \leq w_G(G_I)] = G_I. \tag{6}$$

Notice that there is no adverse selection under general disclosure: $AS_{G_I}(g) = 0$. This is because, having observed $G_I = g$, outside firms have no reason to pay attention to the employer's retention behaviour. Taking expectations over the random variable $w_{G_I}(G_I)$, the expected employment wage is simply expected general human capital

$$W_G = E[G_I]. \tag{7}$$

R_I-**disclosure**

$$w_R(R_I) = E[G_I|R_I, R_I \leq w_R(R_I)] = E[G_I|R_I]. \tag{8}$$

Again, there is no adverse selection, $AS_{R_I}(r) = 0$; in this case, because the disclosed statistic $R_I = r$ supplies finer information than the event that the worker is released, $R_I \leq w_R(r)$. However, there is now regression to the mean, with $r - E[G_I|R_I = r]$ increasing in r. Intuitively, outside firms anticipate that low (high) values of firm I retained productivity may be due to a negative (positive) match and that productivity in a new match will tend to regress to the ex-ante expected value. By the law of iterated expectations, the expected employment wage is still equal to expected general human capital

$$W_R = E[(E[G_I|R_I])] = E[G_I]. \tag{9}$$

$\varnothing_I-$**disclosure**

$$w_{\varnothing_I} = E[G_I|R_I \leq w_\varnothing]. \tag{10}$$

There is now adverse selection, $AS_{\varnothing_I} > 0$. However, in contrast to Akerlof's (1970) lemons model or Greenwald's (1986) application to the labour market, $w_{\varnothing_I}$ does not collapse to the lower support of G_I (even in the absence of a minimum wage) because outside firms anticipate that low values of firm I productivity will partly be redressed by regression to the mean.

Using the above wage comparisons, we now state two results which compare the information structures $\{G_I, R_I, \varnothing_I\}$.

Proposition 1. *For any firm I, G_I-*disclosure *generates maximum expected surplus.*

Proof. Under G_I-disclosure, $w_{G_I}(G_I) = G_I$ and so, from (3), $\Pi_{G_I} = E[(R_I - G_I)^+]$. Summing Π_{G_I} and W_{G_I} gives $E[G_I] + E[(R_I - G_I)^+]$ which is clearly the maximum achievable expected surplus. ■

Under G_I-disclosure a current employer releases its worker whenever $R_I \leq G_I$. Since this implies that the worker is released if and only if there is a negative match, labour is always efficiently allocated across firms. The same cannot be said of the two other information structures. Under R_I-disclosure, firm I releases its worker whenever $R_I < E[G_I|R_I]$ and so it is possible for the worker to be released following a positive match (because G_I is low) and retained following a negative match (because G_I is high). As we now show, $\varnothing_I$-disclosure is less efficient still.

Proposition 2. *For any firm I,*

i. *R_I-disclosure generates $W_{R_I} = W_{G_I}$, $\Pi_{R_I} \leq \Pi_{G_I}$;*

ii. *$\varnothing_I$-disclosure generates $W_{\varnothing_I} \leq W_{G_I}$, $\Pi_{\varnothing_I} \geq \Pi_{G_I}$ with*

$$W_{\varnothing_I} + \Pi_{\varnothing_I} \leq W_{R_I} + \Pi_{R_I} \leq W_{G_I} + \Pi_{G_I}.$$

Proof. The ranking of expected employment wages $W_{\varnothing_I} < W_{R_I} = W_{G_I}$ follows from (7), (9) and (10). The profit ranking $\Pi_{R_I} \leq \Pi_{G_I}$ follows from Proposition 1 and the fact that $W_{R_I} = W_{G_I}$.

To establish $\Pi_{\varnothing_I} \geq \Pi_{G_I}$, note since $E[G_I] \geq w_\varnothing$, it is immediate that $\Pi_{\varnothing_I} = E[(R_I - w_\varnothing)^+] \geq E[(R_I - E[G_I])^+]$. It suffices therefore to establish $E[(R_I - E[G_I])^+] \geq E[(R_I - G_I)^+]$.

The result follows because the variation in G_I tends to cancel the variation in R_I and convex functions 'like' variation. More precisely, note that $E[R_I - E[G_I]|R_I - G_I = x] - E[R_I - G_I|R_I - G_I = x] = E[G_I - E[G_I]|R_I - G_I = x]$ is increasing in x by Assumption 2. This fact, together with the equality of means, implies the random variable $E[R_I - E[G_I]|R_I]$ is riskier than $E[R_I - G_I|R_I]$. Using the convexity of $(x)^+$ gives the result.

To establish $W_{\varnothing_I} + \Pi_{\varnothing_I} \leq W_{R_I} + \Pi_{R_I}$ note that under R_I-disclosure, firm I retains the worker in the event $E[R_I - G_I|R_I] \geq 0$. Hence the R_I-disclosure allocation solves the following optimal allocation problem

$$\max_{0 \leq p(\cdot) \leq 1} E[E[R_I - G_I|R_I]p(R_I)],$$

where p is any probability of retention based on R_I. The $\varnothing_I-$disclosure efficiency level

$$E[(R_I - G_I).1\{R \geq w_\varnothing\}] = E[E[R_I - G_I|R_I].1\{R_I \geq w_\varnothing)]$$

is smaller by revealed preference. ■

The set, $\Omega(\{G_I, R_I, \varnothing_I\})$ of the expected wages and profits that can be generated by the disclosure polices $G_I, R_I, \varnothing_I$, as derived in Propositions 1 and 2, is illustrated in Figure 1, where downward sloping lines depict points of equal expected surplus. When outside firms observe G_I, this generates higher expected surplus for firm I than when the outside firms observe R_I because, as noted above, it results in more efficient retention behaviour. Bertrand competition between outside firms ensures that this expected surplus is split between firm I and its worker. Since the expected employment wage is the same in both cases, firm I must be strictly worse off under R_I-disclosure by virtue of the "smaller pie". Inefficient retention behaviour creates an even "smaller pie" when outside firms have no information. Intuitively, adverse selection depresses wages and causes excess recruitment relative to R_I-disclosure. A key difference now is that, although expected surplus is smaller, the worker receives a smaller share. Proposition 2 tells us that adverse selection drives the expected employment wage $W_{\varnothing_I}$ sufficiently far below W_{G_I} to leave firm I better off.

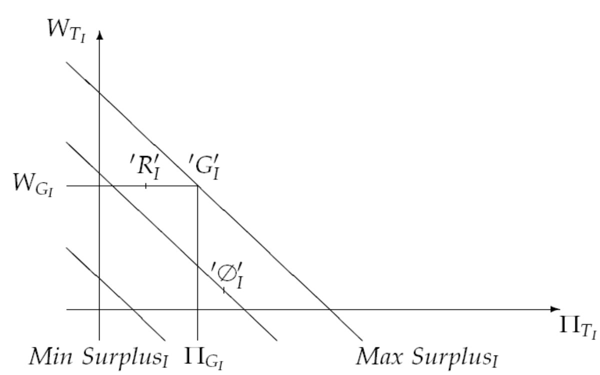


Figure 1: Wages and Profits for
$\Gamma_I = \{G_I, R_I, \emptyset_I\}$.

Notice that, under $\varnothing_I$-disclosure the adverse selection that drives down wages is ameliorated by regression to the mean. Firm I would, therefore, enjoy higher profits if the regression to the mean effect were "turned off". In fact, the best information structure from Firm I's perspective would be one which induces severe adverse selection for any worker it wishes to retain (but not for one the firm wishes to release since this would avoid up-front transfers when the firm must attract the worker initially). We show how an information structure along these lines can arise in Section 3.3.2, below, where we consider information structures that combine R_I and G_I.

3.3 Joint Normal Distribution, Arbitrary Disclosure Policies

For any firm I, the random variables (G_I, R_I) are now assumed to be joint normally distributed. In some of what follows (namely where we calculate wages), we will also assume that G_I and $(R_I - G_I)$ are independent. To avoid confusion, we will term the former case 'joint normality' and the latter the 'independent joint normal' model.

3.3.1 Joint normal information structures

We also limit the set Γ_I of information structures that we consider, to information structures such that (G_I, R_I, T_I) are joint normally distributed with T_I scalar. This assumption rules out mixed structures (e.g. that outside firms observe G_I with probability p and R_I with probability $1-p$), conditional structures (e.g. observe R_I if $G_I \geq 0$) and partitional strategies (e.g. observe either that $G_I \geq 0$ or $G_I < 0$). It does, however, close the model in a natural way.

With (G_I, R_I, T_I) joint normal, a convenient parameterisation is in terms of the linear combination $T_I = aG_I + bR_I + cX_I$, where X_I is a unit variance, independent noise term available via Q_I. Since the random variable T_I can always be rescaled to have any chosen mean and variance without altering its information content, only two of the parameters a, b, and c are free. It is convenient to set $a = 1 - b$, implying that disclosure policies are characterised by the two parameters b and c:

$$T_I = (1-b)G_I + bR_I + cX_I. \tag{11}$$

The above parameterisation simplifies the characterisation of the feasible set. However, it will also be useful to map from these parameters to their associated regression coefficients. In what follows, we will use two simple and two multiple regression coefficients. The simple coefficients are on T_I in the regression of G_I (R_I) on T_I, which we denote by $\beta_{G_I T_I}$ ($\beta_{R_I T_I}$). Normalising $Var(G_I) = 1$, denoting $Var(R_I - G_I)$ by σ^2, and assuming $Cov(G_I, R_I) = 1$, these coefficients write as

$$\beta_{G_I T_I} = \frac{1}{1 + b^2\sigma^2 + c^2}$$

and

$$\beta_{R_I T_I} = \frac{1 + b\sigma^2}{1 + b^2\sigma^2 + c^2}.$$

The multiple coefficients are on T_I (R_I) in the multiple regression of G_I on T_I and R_I, which we denote by $\beta_{G_I T_I . R_I}$ ($\beta_{G_I R_I . T_I}$) and write as

$$\beta_{G_I T_I . R_I} = \frac{(1 - b)\sigma^2}{(1 + \sigma^2)(1 + b^2\sigma^2 + c^2) - (1 + b\sigma^2)^2}$$

and

$$\beta_{G_I R_I . T_I} = \frac{(1 + b^2\sigma^2 + c^2) - (1 + b\sigma^2)}{(1 + \sigma^2)(1 + b^2\sigma^2 + c^2) - (1 + b\sigma^2)^2}.$$

The three information structures discussed in Section 3.2 are easily stated under either parameterisation. G_I-disclosure corresponds to $b = c = 0$, giving $\beta_{G_I T_I} = \beta_{R_I T_I} = 1 = \beta_{G_I T_I . R_I} = 1$ and $\beta_{G_I R_I . T_I} = 0$. R_I-disclosure corresponds to $b = 1$, $c = 0$, giving $\beta_{G_I T_I} = 1/(1 + \sigma^2)$ and $\beta_{R_I T_I} = 1$ with the remaining coefficients undefined.[14] Finally, $\varnothing_I-$disclosure corresponds to $c \to \infty$, giving $\beta_{G_I T_I} = \beta_{R_I T_I} = \beta_{G_I T_I . R_I} = 0$ and $\beta_{G_I R_I . T_I} = 1/(1 + \sigma^2)$. However, in addition to outside firms observing G_I, R_I or X_I, our framework information structures that *combine* these random variables. It is worth highlighting the following cases:

1. *Garbling* G_I with $b = 0, c \neq 0$ ($\beta_{G_I T_I . R_I}$, $\beta_{G_I R_I . T_I} > 0$).
2. No garbling: Linear combinations of G_I and R_I
   (a) *Weighting* $(R_I - G_I)$, with $b > 1, c = 0$ ($\beta_{G_I T_I . R_I} < 0$, $\beta_{G_I R_I . T_I} > 0$).
   (b) *Weighting* G_I, with $1 > b > 0, c = 0$ ($\beta_{G_I T_I . R_I} > 0$, $\beta_{G_I R_I . T_I} < 0$).
   (c) *Differencing* G_I *and* R_I with $b < 0, c = 0$ ($\beta_{G_I T_I . R_I}$, $\beta_{G_I R_I . T_I} > 0$).

Under each of these cases, firm I's retention behaviour conveys information and so there is adverse selection for outsiders in recruitment, $AS_{T_I}(t) \neq 0$.

[14] A singularity occurs at $T_I = R_I$.

3.3.2 Wages and Profits

Our first result expresses $w_{T_I}(t)$ in terms of the regression coefficients, the conditional standard deviation of the random variable $[R_I|T_I = t]$, denoted by $\sigma_{R_I|T_I}$, and the unit normal hazard function h.[15]

Proposition 3. *Under joint normality, the equilibrium employment wage satisfies*

$$w_{T_I}(t) = \beta_{G_I T_I} t - \beta_{G_I R_I . T_I} \sigma_{R_I|T_I} h \left(\frac{\beta_{R_I T_I} t - w_{T_I}(t)}{\sigma_{R_I|T_I}} \right) \tag{12}$$

where finite. Equilibrium adverse selection therefore satisfies

$$AS_{T_I}(t) = \beta_{G_I R_I . T_I} \sigma_{R_I|T_I} h \left(\frac{\beta_{R_I T_I} t - w_{T_I}(t)}{\sigma_{R_I|T_I}} \right). \tag{13}$$

Proof. See Appendix. ■

The employment wage function takes a particularly simple form for garblings of G_I, i.e. disclosures of G_I plus noise. In this case, adverse selection is constant and equilibrium employment wages equal expected outside productivity conditional only on T_I less this constant. To see this note that if T_I is such a garbling, since $R_I - G_I$ is uncorrelated with G_I, it is uncorrelated with the garbling T_I, hence $\beta_{(R_I - G_I)T_I} = 0$, and therefore $\beta_{R_I T_I} = \beta_{G_I T_I}$. Substituting this into the wage equation yields

$$AS_{T_I}(t) = \beta_{G_I R_I . T_I} \sigma_{R_I|T_I} h \left(\frac{AS_{T_I}(t)}{\sigma_{R_I|T_I}} \right), \text{ for all } t,$$

which implicitly defines $AS_{T_I}(t)$ as a constant. We can write this constant as

$$AS_{T_I}(0) = \sigma_{R_I|T_I} k(\beta_{G_I R_I . T_I}). \tag{14}$$

where $k(x)$ is the iteration $k(x) = xh\,(xh\,(...))$, this evidently has a fixed point at zero, the only other is at a point we denote $k \approx 0.302$. It follows that

Corollary 1. *Under joint normality, for T_I any garbling of G_I, the equilibrium employment wage satisfies*

$$w_{T_I}(t) = \beta_{G_I T_I} t - k\sigma_{R_I|T_I} \approx \beta_{G_I T_I} t - 0.3\sigma_{R_I|T_I}. \tag{15}$$

[15] The conditional standard deviation writes as $\sigma_{R_I|T_I} = ((1+\sigma^2) - \left(1 - b + (1+\sigma^2)b\right)^2)^{1/2}$.

The amount of adverse selection is, unsurprisingly, increasing in $\sigma_{R_I|T_I}$ which is a measure of how much uncertainty is left to be attributed to the retention decision. As T_I garbles G_I more, $\sigma_{R_I|T_I}$ increases.

In general, for information structures other than garblings of G_I, of course, adverse selection is not independent of the realised disclosure. Note, however, that, for any given information policy, the *sign* of adverse selection is constant for all realizations of the information available to outside firms, t (it has the same sign as $\beta_{G_I R_I . T_I}$). Moreover at the realisation $T_I = 0$, equation (14) remains valid for any disclosure policy for which there is finite adverse selection. Hence, at the mean realisation of the disclosed statistics, realised wages are ranked according to the conditional standard deviations $\sigma_{R_I|T_I}$.

Proposition 3 solves for the employment wage in terms of a calculable function. Given this function, retention decisions and the current employer's profits can also be calculated for every information structure in Γ_I.[16] We refer to the upper boundary of the set of wages and profits, $\Omega(\Gamma_I)$, as the *efficiency frontier,* since on this boundary there is no information structure that yields the same expected wage for the worker without reducing the firm's expected profit. Our next result (calculated using (12) with G_I and $(R_I - G_I)$ assumed independent) shows that the efficiency frontier does not consist of policies which garble G_I with noise, rather G_I is combined with R_I.

Result 4. *In the independent joint normal model, for any firm I, the efficiency frontier of the set $\Omega(\Gamma_I)$ is generated by the disclosure policies $T_I = (1 - b)G_I + bR_I$, with $b < 1$, $c = 0$.*

1. *With $1 > b > 0$, expected employment wages W_{T_I} are greater than $E[G_I]$.*
2. *With $b = 0$, expected employment wages equal $E[G_I]$.*
3. *With $b < 0$, expected employment wages are less than $E[G_I]$.*
4. *A policy with $b = 1, c = 0$ is on the lower boundary of the set.*
5. *A policy with $b > 1, c = 0$ induces extreme adverse selection, expected employment wages are infinite.*

It is worth pausing to discuss features of the set of wage, profit pairs that different information structures can generate and, in particular, its efficiency frontier plotted in Figure 2 (for values of $b \in [1/3, -4/3]$). We first consider what is required for an

[16] All calculations here and for Results 8 and 9, and Figures 2, 3, 5 and 6 are available from the authors as Mathematica Notebook files.

information structure to drive the expected employment wage below $E[G_K]$, and then how a given reduction in W_{T_I} can be achieved most efficiently.

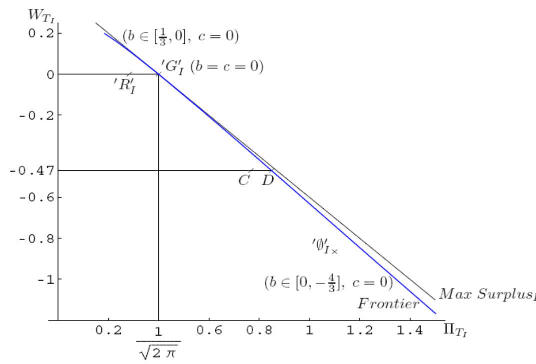


Figure 2: The Efficiency Frontier, plotted for
$G_I \sim N[0, 1]$ and $R_I \sim N[0, 1]$.

To drive the expected employment wage below $E[G_I]$, the expected adverse selection must be positive. From (13), $AS_{T_I}(t)$ is positive only if $\beta_{G_I R_I . T_I} > 0$, giving a simple and intuitive condition. Firm I's retention decision will create adverse (rather than positive) selection—i.e. depress $w_{T_I}(t) = E[G_I | T_I = t, R_I \leq w_{T_I}(t)]$ below $E[G|T = t]$—if and only if a lower value of R_I is bad news for G_I given T_I.

One might think that this condition will hold whenever retention behaviour is informative. As Figure 3 illustrates, this is not the case; there are information structures that lead to an expected wage for the worker that lies *above* $E[G_I]$, that is there is positive rather than adverse selection. The unifying feature of these information structures with $\beta_{G_I R_I . T_I} < 0$ is that G_I is combined with R_I, with more weight on G_I.[17] Of course, as Figure 2 also illustrates, there are many information structures that *do* satisfy this condition and hence drive the expected employment wage below $E[G_K]$. Indeed, of the four types of 'combined' structures listed at the end of Section 3.3.1, above, only the third (weighting G_I) fails in creating adverse selection. The question is therefore why some of these information structures are more efficient than others, and in particular why the fourth type (differencing G_I and R_I, with $b < 0$ and $c = 0$) traces out the efficiency frontier below $E[G_I]$?

[17] With no noise ($c = 0$), any $b \in (0, 1)$ will generate positive selection. With noise, the range of policies becomes more tightly bounded above 0 and below 1.

To see the answer, note that, even when two information structures generate the same expected employment wage, the *distribution* of adverse selection over t may vary. Figure 3 illustrates, depicting two information structures that generate the same expected adverse selection (the area under both quantile functions is ≈ 0.47) but with very different distributions. A garbling of G_I (policy C) depresses wages uniformly: AS_{T_I} is constant at every quantile of $T_I = G_I + \sqrt{5}/2X_I$. In contrast, differencing R_I and G_I (policy D) imposes a lot of adverse selection at low quantiles of $T_I = 3/2G_I - 1/2R_I$ and little adverse selection at high quantiles (and indeed none at $p = 1$). This is efficient, as low quantiles are associated with good matches, while high quantiles are associated with bad matches. Since this information structure depresses wages most when retention is efficient and least when retention is inefficient, it generates a higher surplus than the information structure where wages are depressed uniformly (in Figure 2 the wage-profit pair associated with policy C lies to the left of the pair associated with policy D).

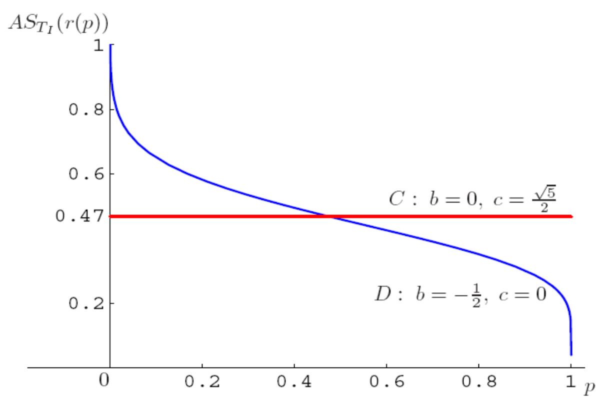


Figure 3: Adverse Selection of Quantiles of T_I plotted for $G_I \sim N[0,1]$ and $R_I \sim N[0,2]$.

The above logic explains why garbling G_I, the first type of information structure, is less efficient than differencing G_I and R_I, the fourth, and indeed why a garbling of a differenced estimate of inside and outside productivity ($b < 0, c \neq 0$) lies inside the efficiency frontier. All that remains is to consider the second type of policy (weighting $R_I - G_I$ with $b > 1, c = 0$). The reason why this type of policy fails to trace out the efficiency frontier is simple. By weighting the disclosure statistic towards $R_I - G_I$, that is match quality, the information structure eliminates regression to the mean. This leaves adverse selection to hit with full force, depressing wages not simply below $E[G_I]$ but as far as the lower support.

This logic also highlights the strength of certain information structures outside the set of joint normally distributed information that we are considering here. In particular, a policy which discloses G_I whenever $R_I - G_I < 0$ and discloses R_I otherwise, induces no allocative inefficiency—those workers expected to be more productive at other firms are released—but induces full adverse selection, driving the second period wage as far as the lower support of G_I on those workers who are efficiently retained.

Having discussed how different information structures affect expected wages and profits, we now extend the model, endogenizing the information structures associated with different firms and tracing out implication for labour market outcomes.

4 A Two period model of labour market competition

In this section, we extend the basic model presented above. We suppose that there are two periods of employment. In the first period all potential employers hold the same information about potential employees. Employees are attracted to firms, not only by the wages offered, but also by the career prospects that a firm offers. These career prospects arise from (exogenous) variation in the extent to which first period employment at a firm augments an employee's general human capital, and endogenous variation through a firm's strategic choice of an information disclosure policy, which affects the information available to rival employers competing for the worker in the second period of employment.

Specifically, we consider an economy that consists of N firms (each with a single position available) and $M < N$ workers. Firms compete to hire, or retain, a worker in periods one and two. The first period employer, firm I, is the inside firm in the second period, and wages in the second period are determined as in Section 2. It is a convenient simplification to refer to first period employment as training and to suppose that the employee is not productive in the first period, but gains skills that depend on the identity of the first period employer.

We take the view that certain firms, typically innovative or in some other way privileged, naturally enable workers to acquire more skills. As such, we do not assume that $E[G_I] = E[G_{I'}]$ for all I, I'. Rather, we make the next simplest assumption which is to distinguish between "skill-augmenting" and "competitive" firms. When we wish to invoke this distinction we will refer to a typical skill-augmenting firm as firm K and a typical competitive firm as firm J (I continues to denote a generic firm).

Assumption 3. *There are $N_1 < M$ skill-augmenting firms and $N - N_1$ competitive firms in the economy. Competitive firms are exchangeable: for each pair of com-*

petitive firms J, J', (Q_J, Y_{JI}) is equal in distribution to $(Q_{J'}, Y_{J'I})$. For each skill-augmenting firm K, (G_K, R_K) has the same distributions as $(G_J + \Delta_K, R_J + \Delta_K)$ for some $\Delta_K > 0$. In other words skill-augmenting firms, simply add Δ_K to the general human capital of their employees.

Just as Assumption 1 simplifies second period labour market competition, Assumption 3 simplifies first period labour market competition. Skill-augmenting firms are advantaged and in short-supply, and will (therefore) all hire one worker at the prevailing wage. This leaves the remaining $N - N_1$ exchangeable firms to Bertrand compete for the $M - N_1$ free workers. It is this Bertrand competition that determines the prevailing wage. Our concern will be to explore how the employment policies of different firms vary with the size of the skill gap. We remark that the skill gap is treated here as exogenous but in a natural variant of the model it could arise from firms choosing to invest in general human capital, as briefly discussed in Section 6.

When discussing labour market outcomes, it will be of interest to consider a variant of Assumption 3 in which N_1 is a variable parameter which may exceed the number of workers M. In this event (corresponding to a high demand for labour in the skill-augmenting sector), the employment wage will be set by skill-augmenting firms themselves.

Assumption 3′. *There are N_1 exchangeable skill-augmenting firms and $N - N_1$ exchangeable competitive firms in the economy. For each skill-augmenting firm K, the skill gap $\Delta = E[G_K] - E[G_J]$ is positive.*

Assumption 3′ differs from Assumption 3 in that all the skill-augmenting firms are identical. This will serve to make wage setting Bertrand-competitive in the case where $N_1 > M$.

First Period Contracts It remains to describe, first period competition: The N firms compete to hire a worker in the first period through publicly observable contracts. For a given firm I, a contract specifies:

1. A training wage $w_I \geq 0$. The worker is credit constrained.

2. A disclosure policy $T_I = T_I(Q_I)$ from a set of possible disclosure policies (or information structures) Γ_I. Equivalently, having characterized the set of feasible second period wage, profit pairs that can be generated given the set of disclosure Γ_I, it is convenient to think of the firm as choosing such a pair (W_{T_I}, Π_{T_I}) from the feasible set $\Omega(\Gamma_I)$.

Note that we assume firms cannot disclose what they do not know and we do not allow firms to manipulate the statistics that they disclose. We believe these not only to be useful assumptions for tractability, but plausible ones when we interpret the information disclosed to outside firms as arising from choices about organizational design and the organization of production (for example, on the extent and composition of teamwork rather than solo production, the extent of hierarchy and the level of individual discretion).[18] Moreover, reputation concerns (and the desire to hire other workers in the future) might also allow firms to make credible commitments about more direct disclosure policies (such as consulting firms choosing whether or not to cite juniors involvement in final reports, or decisions to give them more or less access to clients). Note that while many of these examples concern discrete rather than continuous scalar disclosure statistics, similar economic forces should be present, and our assumptions on distributions as well as the disclosed statistic are analytically convenient.

5 Analysis

Our simplifying assumptions enable us to characterise equilibria piecemeal by solving two maximisation problems, one for a representative competitive firm J and another for a skill-augmenting firm K. Note, that for a given disclosure policy T_I, the second period is identical to the model described in Section 2. In particular, the expected second period wage is given by (2) and expected second period profit by (3).

Workers in assessing first period contracts take into account both the wage offered and, also, the expected second period wage. This, in turn, depends on the identity of the firm (and the extent of general human capital that she anticipates acquiring in the training period) and the disclosure policy to which the firm commits through the contract.

Competitive firms attempt to hire one of the $M - N_1$ 'free' workers in the first period. Since they face fierce competition, they attract workers by transferring as much surplus as possible to the worker (up to the zero profit constraint). They transfer surplus most easily through a higher first period wage. Specifically, by offering to pay their entire expected second period profit in training wages: $w_J = \Pi_{T_J}$. Thus, the problem facing a competitive firm J when choosing a disclosure policy is simply one of expected surplus

[18] Note that such choices over organization designs are likely to involve productive costs. We abstract from these here, though (to the extent that they are easily quantified) they can be easily incorporated into the model.

maximisation

$$\max_{(W_{T_J},\Pi_{T_J})\in\Omega(\Gamma_J)} W_{T_J}+\Pi_{T_J}. \tag{16}$$

Following, Proposition 1, this is maximized by choosing G_J-disclosure when this disclosure policy is available.

This behaviour by competitive firms pins down a worker's outside-option. Any worker turning down a training contract at a skill-augmenting firm can receive $W_{T_J}+\Pi_{T_J}$ at a competitive firm. Denoting this equilibrium outside-option by $\bar{U}$, the problem facing a skill-augmenting firm K (or indeed any other) can be written as

$$\max_{(W_{T_K},\Pi_{T_K})\in\Omega(\Gamma_K)} W_{T_K}+\Pi_{T_K}-\bar{U}+(\bar{U}-W_{T_K})^{-}, \tag{17}$$

where $(x)^{-}$ denotes x when negative, zero otherwise. Notice that when $\bar{U}>W_{T_K}$, the maximand in (17) differs from that in (16) only by a constant, and when $\bar{U}\leq W_{T_K}$ it coincides with (3); the firm chooses the training wage and disclosure policy to maximize its second period profits.

Overall, we define an equilibrium as an array of training contracts for competitive firms $\{w_J,T_J\}_J$ each satisfying surplus maximisation (16), and an array of training contracts for skill-augmenting firms $\{w_K,T_K\}_K$ each satisfying (worker participation constrained) profit maximisation (17). The maximisation problems are entirely straightforward, given our characterization of the feasible set $\Omega(\Gamma_I)$.

5.1 Equilibrium Contracts and Labour Market Outcomes: General Results

Here, we can use the characterization of second period wages and profits from Section 3.2.2. In addition to using these to characterise contracts (which are typically hard to observe), we are also interested in their consequences for observable labour market outcomes. The following all depend heavily on the disclosure policy and are therefore characterised alongside equilibrium contracts for different firms J,K:

1. Probability of labour turnover;
2. Unconditional wage distribution for workers;
3. Conditional wage distributions for retained and released workers.

The following result holds regardless of Γ_J (providing G_J-disclosure is in this set).

Proposition 5. *For each competitive firm J with $G_J \in \Gamma_J$,*

i. Contracts: *The offered contracts feature G_J-disclosure and a training wage of $w_J = \Pi_{G_J}$.*

ii. Labour market outcomes: *Labour turnover takes place with probability* $\Pr[R_J < G_J]$. *The distribution of employment wages is identical to the distribution of G_J. If G_J and $(R_J - G_J)$ are independent, the distribution of wages is the same for both retained and released workers; if G_J and $(R_J - G_J)$ are affiliated the distribution of wages for retained workers first degree stochastically dominates that for released workers.*

Proof. A competitive firm J chooses G_J-disclosure since this maximises expected surplus. Bertrand competition (zero profits) ensures that $w_J = \Pi_{G_J} = E[(R_J - G_J)^+]$. The labour market outcomes follow immediately from the choice of disclosure policy. ∎

Proposition 5 is intuitive, the more striking results will appear when we contrast with the situation of skill-augmenting firms.

Behaviour by competitive firms pins down $\bar{U} = E[G_J] + E[(R_J - G_J)^+]$. This observation, together with Proposition 2, enables us to solve the maximisation problem in (17), and hence characterise the equilibrium behaviour of, and resulting labour market outcomes for, skill-augmenting firms with available disclosure policies $\Gamma_K = \{G_K, R_K, \varnothing_K\}$.

Proposition 6. *For a skill-augmenting firm K with $\Gamma_K = \{G_K, R_K, \varnothing_K\}$,*

1. *If $E[G_K]$ is small ($E[G_K] \leq E[G_J] + E[(R_J - G_J)^+]$ suffices), then*

i. Contracts: *G_K-disclosure and a training wage of* $w_K = \max\{\bar{U} - E[G_K], 0\}$.

ii. Labour market outcomes: *Labour turnover takes place with probability* $\Pr[(R_K - G_K) < 0]$. *The distribution of employment wages is identical to the distribution of G_K and, if G_K and $(R_K - G_K)$ are independent, is the same for both retained and released workers.*

2. *If $E[G_K]$ is sufficiently large, ($E[G_K] > E[G_J] + E[|R_J - G_J|]$ suffices), then*

i. Contracts: *$\varnothing_K$-disclosure and a training wage of* $w_K = \max\{\bar{U} - W_{\varnothing_K}, 0\}$.

ii. Labour market outcomes: *Labour turnover takes place with positive probability (less than*
$\Pr[(R_K - G_K) < 0]$*). The distribution of employment wages is degenerate at $W_{\varnothing_K} < E[G_K]$ for both retained and released workers.*

Proof. If $E[G_K] \leq \bar{U}$, then G_K-disclosure maximises surplus and the training wage $w_K = \bar{U} - E[G_K]$ just meets the worker participation constraint. Therefore this policy maximises firm K expected profit subject to the worker participation constraint. If $E[G_K] > \bar{U}$, then G_K-disclosure with training wages $w_K = 0$ remains efficient but the worker receives some of the surplus in excess of the participation constraint. In a neighbourhood where $E[G_K] - \bar{U}$ is positive but small, the surplus paid to the worker remains less than the efficiency loss of switching to another disclosure policy.

If $E[G_K] - \bar{U}$ is positive and large enough, the extra surplus paid to the worker under G_K-disclosure will exceed the efficiency loss under null disclosure. To verify this consider the two cases (a) $w_{\varnothing_K} \geq \bar{U}$, (b) $w_{\varnothing_K} < \bar{U}$. For case (a) Proposition 2(ii) establishes that profit is higher under null disclosure, training wages are set at zero. In case (b) firm profit is $E[(R_K - w_{\varnothing_K})^+] - (\bar{U} - w_{\varnothing_K}) \geq E[R_K - w_{\varnothing_K}] - \bar{U} + w_{\varnothing_K} = E[R_K] - \bar{U}$. Hence, it suffices that $E[R_K] - \bar{U} \geq E[(R_K - G_K)^+]$. Equivalently, $E[R_K - G_K] + E[G_K] - \bar{U} \geq E[(R_K - G_K)^+]$, or $E[G_K] - \bar{U} \geq -E[(R_K - G_K)^-] = E[(G_K - R_K)^+]$. Substituting for $\bar{U}$, $E[G_K] \geq E[G_J] + E[(R_J - G_J)^+] + E[(R_K - G_K)^+]$. The result follows since, by Assumption 3, $R_J - G_J$ and $R_K - G_K$ have the same (symmetric) distributions. ■

Figure 4 displays the situation. Suppose the worker's outside-option is at the level of point A (above W_{G_K}). In this case, even the high expected employment wage under G_K-disclosure, fails to (strictly) satisfy the worker's participation constraint. To hire the worker, a skill-augmenting firm K must surrender expected profit by paying a positive training wage. It will adopt a policy of G_K-disclosure, since this maximises the "pie" and, with the worker's share fixed, leaves the largest possible share for the firm.

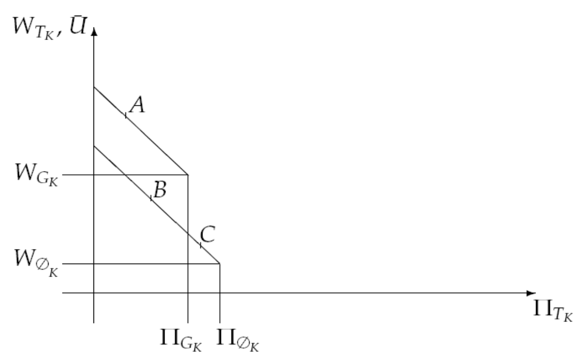


Figure 4: Disclosure Policies given Reservation Utility Constraints.

Alternatively, suppose the worker's outside-option is at the level of point B (below but in the neighbourhood of W_{G_K}). In this case, the expected employment wage under G_K-disclosure more than meets the worker's outside-option. The ideal strategy for firm K would be to offer a negative training wage that held the worker to her outside-option and increased expected profit by $W_{G_K} - \bar{U}$. However, given worker credit constraints, this is not possible. With the firm unable to claw back rent via the training wage, switching to a disclosure policy that generates adverse selection starts to look attractive. Unfortunately for the firm, switching to $\varnothing_K-$disclosure destroys surplus. Once it has compensated the worker for the shortfall in utility $(\bar{U} - W_{\varnothing_K})$ by paying a positive training wage, the remaining level of expected profit is less than that achievable under G_K-disclosure; i.e. in Figure 2, point B lies to the *left* of Π_{G_K}. In contrast, suppose the worker's outside option is at the level of point C (some distance below W_{G_K}). Now the firm will choose $\varnothing_K$-disclosure. In this case the rent to be recouped is large enough to justify the destruction of surplus; i.e. point C lies to the *right* of Π_{G_K}.

Proposition 6 takes a restricted set of polices for comparison. This, it shares with most of the disclosure literature. The implications for labour market outcomes are rather stark, especially in that the distribution of wages for workers in the K firms becomes degenerate. We now allow for a wider class of disclosure policies, again, by specialising to a joint normal distribution.

5.2 Equilibrium Contracts under joint normality

We return to the framework of Section 3.3 and suppose that the firm can choose any disclosure policy of the form (11).[19] We start by stating that firms never adopt disclosure policies which induce a negative conditional correlation between estimates of inside productivity and outside productivity. Intuitively, this makes sense since if such a negative correlation were present, then the event that a worker is not retained becomes 'good news' regarding the outside productivity of the worker. This is the opposite of a winners' curse and the positive rather than adverse selection effect would serve to drive up the wage offers of competing employers, making it more expensive to retain workers. This, in effect, transfers surplus from the firm to the worker; however, the firm can transfer surplus directly through first period wages, rather than through a disclosure policy that destroys overall surplus by misallocating the worker.

[19] As various seminar participants have pointed out, this class of policies may be broader than might be feasibly implemented through organization design. In this case, the analysis here can be viewed as highlighting economic mechanisms and suggesting forces at work when firms choose from restricted and (perhaps discrete) disclosure policies.

Proposition 7. *Under joint normality, neither competitive nor skill-augmenting firms ever choose a disclosure policy with* $\beta_{G_I R_I . T_I} < 0$.

Proof. The fact that each competitive firm J chooses G_J-disclosure follows from Proposition 1. Suppose the skill-augmenting firm chooses $\beta_{G_K R_K . T_K} < 0$. Then expected second period profit is

$$\begin{aligned} E[(R_K - w_{T_K}(T_K))^+] &= E[(R_K - E[G_K|T_K] - AS_{T_K}(T_K))^+] \\ &\leq E[(R_K - E[G_K|T_K])^+] \leq E[E[(R_K - G_K)^+|T_K]] = E[(R_K - G_K)^+], \end{aligned}$$

where the first inequality follows from $AS_{T_K}(T_K) \leq 0$ and the second follows from application of Jensen's inequality. A disclosure policy with $\beta_{G_K R_K . T_K} < 0$ therefore leads to lower expected second period profit than general disclosure. ■

Finally, we can use our characterization of the feasible set of wage, profit pairs from Result 4, to characterize the disclosure policies chosen by skill-augmenting firms is described as follows, where $\bar{U} = E[G_J] + E[(R_J - G_J)^+]$.

Result 8. *In the independent joint normal model, for a skill-augmenting firm* K*,*

1. *If* $E[G_K]$ *is small (*$E[G_K] \leq \bar{U}$ *suffices), then contracts are* G_K*-disclosure and a training wage of* $w_K = \max\{\bar{U} - E[G_K], 0\}$.

2. *If* $E[G_K]$ *is large (*$E[G_K] > \bar{U}$ *suffices), then contracts are a disclosure policy* $T_K = (1-b)G_K + bR_K$*, with* b *decreasing in* $E[G_K]$*, and a training wage of* $w_K = 0$.

This result follows directly from the calculation of the efficiency frontier. It is helpful to compare the equilibrium contracts chosen by a skill-augmenting firm when Γ_K is joint normal with the case discussed in Section 5.1 where $\Gamma_K = \{G_K, R_K, \varnothing_K\}$. The first part of the result is simply a restatement of the first part of Proposition 6: if the general skills acquired at firm K are expected to be low, then firm K chooses G_K-disclosure to meet the worker's reservation utility in the most efficient manner possible. However, if firm K is advantaged, so that the general skills acquired at firm K are expected to exceed the worker's reservation utility (as pinned down by the competitive fringe), then the firm will switch to a policy that generates adverse selection. Of course, it is in the firm's interest to depress wages as efficiently as possible and so the disclosure policy will be a (noiseless) difference of inside and outside productivity. As the size of the skill gap increases, firm K claws back rent from the worker by increasing expected adverse selection (decreasing b further below zero thereby increasing $\beta_{G_K R_K . T_K}$).

5.2.1 Comparative Statics of Labour Market Outcomes

This section traces the map from technological differences, via human capital management policies through information management to labour market outcomes at the level of the firm.

With $Var(G_K)$ normalised to 1, the technological position of a skill-augmenting firm K is characterised by three parameters: expected general human capital formation $E[G_K]$, expected match quality $E[R_K - G_K]$ and the variance of match quality $Var(R_K - G_K)$. The following result describes how changes in these parameters impact on labour market outcomes in the skill-augmenting sector (holding the technological position of the competitive sector fixed).

Result 9. *In the independent joint normal model,*

1. *If $E[G_K]$ is small ($E[G_K] \leq \bar{U}$ suffices),*

i. *the probability of labour turnover is independent of $E[G_K]$ and $Var(R_K - G_K)$ and is decreasing in $E[R_K - G_K]$;*

ii. *the distribution of employment wages is identical to the distribution of G_K.*

2. *If $E[G_K]$ is large ($E[G_K] > \bar{U}$ suffices)*

i. *the probability of labour turnover is increasing in $Var(R_K - G_K)$ and decreasing in $E[G_K]$ and $E[R_K - G_K]$;*

ii. *the distribution of employment wages has mean $\bar{U}$ but is no longer normal, with inequality decreasing in $Var(R_K - G_K)$ and increasing in $E[G_K]$ and $E[R_K - G_K]$.*

Note that the model and this result assume that each firm has a single worker, but they are suggestive on the relationship between wage dispersion and performance at the firm level. Specifically, skill-augmenting firms are able to earn profits through their rare ability to augment human-capital and so should be observed as more profitable. This profitability arises since they are able to extract some rents from workers, first by driving down training wages leading to greater wage inequality between first- and second-period workers, but also through choosing innovative disclosure policies that compress second-period employment wages, suggesting reduced second-period wage dispersion.[20]

[20] Empirically, however "first" and "second" periods have not been distinguished, which may account for mixed empirical results (See, for example, Martins (2008) and Lallemand, Plasman, and Rycx (2007) and the summary of the literature therein). Typically, the literature has posited that wage dispersion

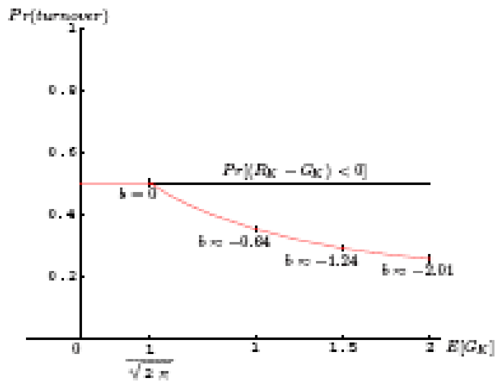
Result 9 is illustrated in Figures 5 and 6 (plotted for $E[G_J] = E[R_J - G_J] = 0$, $Var(G_J) = Var(R_J - G_J) = 1$, implying $\bar{U} = E[(R_J - G_J)^+] = 1/\sqrt{2\pi}$). We start by discussing the consequences of technological changes in the skill-augmenting sector for labour turnover.

Our analysis of the general model established that, for values of $E[G_K] \leq \bar{U}$, labour turnover occurs with probability $\Pr[R_K < G_K]$ and is therefore independent of $E[G_K]$ by Assumption 3. Figure 5 Panel a plots the case where match quality is distributed symmetrically around zero, giving rise to a turnover rate of 50% (the top line). Consider a technological change that increases $E[G_K]$ above $\bar{U}$. A skill-augmenting firm will respond by adjusting its disclosure policy (decreasing b) to claw back the associated rent from its worker. The adverse selection associated with this change in organisational design depresses labour turnover.

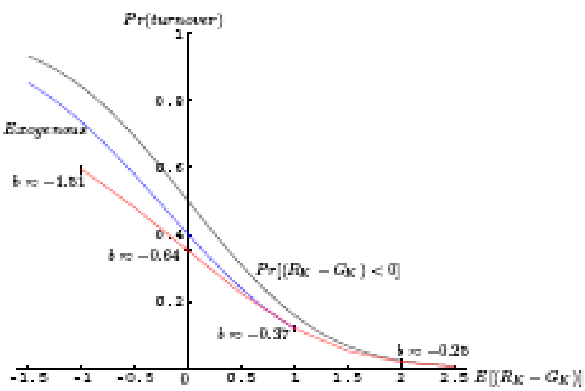
As one might expect, labour turnover also decreases with a change in technology that 'improves matching' ($E[R_K - G_K]$). Here, however, endogenous organisational design *dampens* the effect. Figure 5 Panel b illustrates by plotting the turnover rate against $E[R_K - G_K]$, holding $E[G_K] = Var(R_K - G_K) = 1$. If $E[G_K] \leq \bar{U}$ the turnover rate is equal to $\Pr[(R_K - G_K) < 0]$ which is evidently decreasing in $E[R_K - G_K]$. With $E[G_K] > \bar{U}$, however, firm K will seek to impose adverse selection. Suppose that $E[R_K - G_K]$ declines below 1 but that firm K (sub-optimally) leaves its disclosure policy fixed at $b \approx -0.37$. Labour turnover increases but at a slower rate than $\Pr[(R_K - G_K) < 0]$ (compare the middle and the highest line in the Figure). In other words, adverse selection mutes the effect of a decline in $E[R_K - G_K]$ on labour turnover. This dampening effect becomes stronger if firm K adjusts its disclosure policy to keep its worker at $\bar{U}$ (the bottom line in the Figure). As $E[R_K - G_K]$ declines, regression to the mean ameliorates adverse selection. *Larger* deviations (more negative b) from G_K-disclosure are therefore necessary to generate sufficient adverse selection and these adjustments depress labour turnover further below $\Pr[(R_K - G_K) < 0]$.

may explain firm performance and focuses on worker effort, in particular, contrasting the incentives and wage dispersion that arise in tournaments (as in Lazear and Rosen, 1981) with the collaboration that arises from fairness and low wage dispersion (Akerlof and Yellen, 1990 and Fehr and Schmidt, 1999) or the incentives for influence activities and rent-seeking that may be prevalent with high wage-dispersion (Milgrom, 1988 and Milgrom and Roberts, 1990) or sabotage in tournaments (Lazear, 1989). Our results, suggest that firm performance and the extent of wage-dispersion may both arise from the extent to which a firm has an advantage over its rivals in augmenting general human capital (or providing a platform for a successful career).

Panel a: Plotted for $Var(G_K) = Var(R_K - G_K) = 1$, $E[R_K - G_K] = 0$, $\bar{U} = \frac{1}{\sqrt{2\pi}}$.



Panel b: Plotted for $E[G_K] = Var(G_K) = Var(R_K - G_K) = 1$, $\bar{U} = \frac{1}{\sqrt{2\pi}}$.



Panel c: Plotted for $E[G_K] = Var(G_K) = 1$, $E[R_K - G_K] = 0$, $\bar{U} = \frac{1}{\sqrt{2\pi}}$.

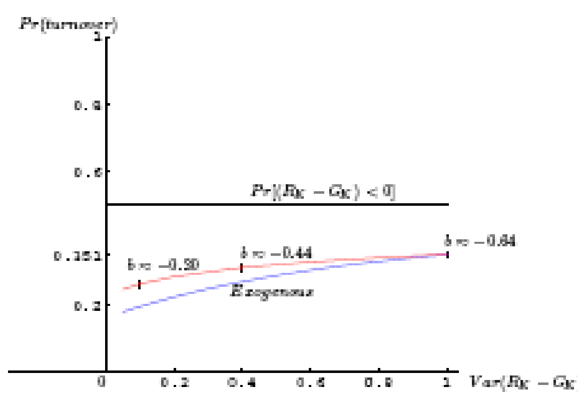


Figure 5: The Probability of Labour Turnover.

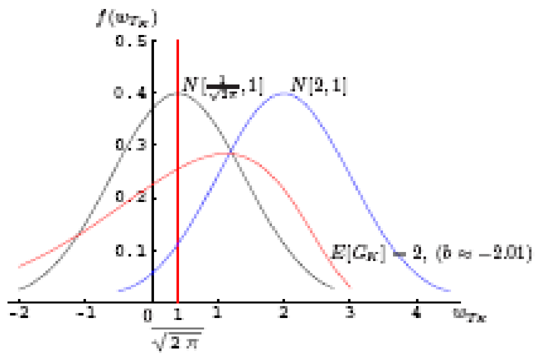
Figure 5 Panel c illustrates the impact of $Var(R_K - G_K)$, holding $E[G_K] = 1$, $E[R_K - G_K] = 0$. Again, with $E[G_K] > \bar{U}$, firm K will seek to impose adverse selection. Suppose that $Var(R_K - G_K)$ declines below 1 but that firm K (sub-optimally) leaves its disclosure policy fixed at $b \approx -0.64$. Labour turnover decreases further below $\Pr[(R_K - G_K) < 0]$ (compare the bottom and highest line in the Figure). This effect is muted, however, if firm K adjusts its disclosure policy to keep its worker at $\bar{U}$ (the middle line in the Figure). Since poorer information about match quality reduces the regression to the mean effect, adverse selection hits harder. *Smaller* deviations (less negative b) from G_K-disclosure are necessary to generate sufficient adverse selection and this depresses labour turnover less below $\Pr[(R_K - G_K) < 0]$.

Turning to the distribution of employment wages at firm K: for values of $E[G_K] \leq \bar{U}$, the distribution of employment wages is identical to the distribution of G_K. Given our assumption that G_K and $(R_K - G_K)$ are independent, the distributions for retained and released workers are identical. For higher values of $E[G_K]$, firm K adjusts its disclosure policy to keep the expected employment wage equal to $\bar{U}$. Since adverse selection is greater at lower quantiles of T_K (recall Figure 3), the distribution of employment wages is no longer normal, but becomes negatively skewed.

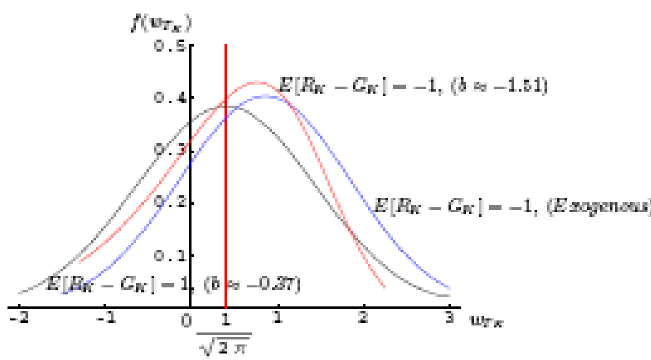
Figure 6 Panel a illustrates. With $E[G_K] = 1/\sqrt{2\pi}$, firm K chooses G_K-disclosure and so the distribution of employment wages following training at firm K simply reflects the distribution of general human capital (i.e. $N[1/\sqrt{2\pi}, 1]$). If $E[G_K] = 2$ but firm K chooses G_K-disclosure, then the distribution of employment wages is translated to $N[2, 1]$. Of course, it is optimal for the firm to alter its disclosure policy, in this case to $b \approx -2$. This adjustment drives the mean employment wage back down to $\bar{U}$ and, with adverse selection hitting hardest on the low T_K quantiles, skews the distribution to the left.

The remaining panels in Figure 6 hold expected general human capital formation fixed and vary the distribution of match quality $(R_K - G_K)$. Suppose that $E[G_K] = Var(R_K - G_K) = E[R_K - G_K] = 1$ and that firm K chooses a disclosure policy with $b \approx -0.37$. If $E[R_K - G_K]$ declines, so that the expected retained human capital is lower, but firm K (sub-optimally) leaves its disclosure policy fixed then there is less adverse selection. As Panel b illustrates, this change in adverse selection both compresses, and increases the mean of, the distribution of employment wages. Since the expected employment wage now exceeds the worker's reservation utility, it is optimal for the firm to alter its disclosure policy, here to $b \approx -1.51$. This adjustment reintroduces adverse selection and skews the distribution of employment wages to the left.

Panel a: Plotted for $Var(G_K) = Var(R_K - G_K) = 1$, $E[R_K - G_K] = 0$, $\bar{U} = \frac{1}{\sqrt{2\pi}}$.



Panel b: Plotted for $E[G_K] = Var(G_K) = Var(R_K - G_K) = 1$, $\bar{U} = \frac{1}{\sqrt{2\pi}}$.



Panel c: Plotted for $E[G_K] = Var(G_K) = 1$, $E[R_K - G_K] = 0$, $\bar{U} = \frac{1}{\sqrt{2\pi}}$.

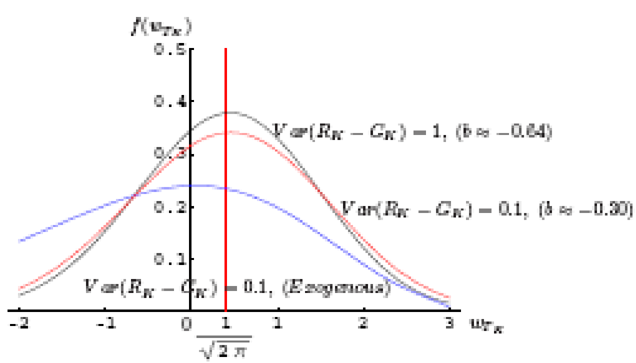


Figure 6: The Distribution of Employment Wages.

Finally, consider the impact of a change in $Var(R_K - G_K)$. Suppose that $E[G_K] = Var(R_K - G_K) = 1$, $E[R_K - G_K] = 0$ and that firm K chooses its optimal disclosure policy with $b \approx -0.64$. If $Var(R_K - G_K)$ declines but firm K (sub-optimally) leaves its disclosure policy fixed there is *more* adverse selection. As Panel c illustrates, this change in adverse selection disperses, and decreases the mean of, the distribution of employment wages. Since the expected wage is below $\bar{U}$, it is optimal for the firm to alter its disclosure policy, now to $b \approx -0.30$. This adjustment removes adverse selection, reducing the left skewness of distribution of employment wages. Indeed, as Panel c makes clear, the overall effect of a decrease in the variance of $R_K - G_K$ resembles a mean-preserving spread in wages.

Note that one can interpret an increase in the variance of an estimate as an improvement in information. This follows since conditioning on extra information produces a mean preserving spread of conditional expectations: $E[Y_{KK} - Y_{KJ}|Q_K, Q'_K]$ is a mean preserving spread of $E[Y_{KK} - Y_{KJ}|Q_K]$. An increase in $Var(R_K - G_K)$ therefore follows from technological changes that give firm K a better idea of worker match quality. Improvements in information about match quality therefore compress wage distributions. This contrasts with improvements in information about general human capital (when firms are competitive).

6 Concluding Remarks

This paper has made two related contributions. First, we have introduced a model where workers may vary in both their general ability and their match with particular firms. In this context, we considered the implications of different information structures on wages and profits, highlighting that information structures have implications not only for the distribution of surplus between an employer and worker, but, also, for the aggregate surplus through the possibility of misallocation. Second, we characterised optimal information management policies. These policies are determined according to whether the employer is constrained principally by the need to attract workers (participation constraints) or by an inability to fully leverage acquired general human capital talent (credit constraints). As has been recognised since Akerlof (1970), the distribution of information can have striking, apparently disproportionate, effects on market outcomes. Our analysis has also highlighted that, where organisational responses to technological change impact through information flows, the consequences for wages and turnover rates may appear to be disproportionately large.

There are several natural extensions that might be considered beyond generalizing the results to other wage determination protocols, other types of disclosure policy, or different distributional assumptions. In particular, we briefly discuss broadening the strategic decisions available to employers to include additional decisions on training and information acquisition.

First, it is natural to endogenize the extent to which a firm augments human capital in the training period. If a firm can commit to provide a level of training which would supplement a worker's natural ability then in the initial period of competition, firms would compete by offering wages, and committing to both a disclosure policy and training. As long as training is efficient (that is, as long as the second period productivity it generates is greater than the first period cost) then the most cost-effective means to attract workers is by providing more training. At some point, however, this might involve worker paying for these general skills up-front, as proposed by Becker (1964). Of course, this is impractical when the sums involved are significant, especially for credit constrained workers at the outset of their careers. Nevertheless, in the manner described in Section 5, the worker can effectively pledge expected second period wages by agreeing to a contract with an information disclosure policy that leads to higher expected second period wages.

In contrast to our results above, even when all firms are identical, they may choose to restrict the information that is released when allowing for a training decision. Again, competition among firms suggest that firms seek to create as much surplus as possible and transfer it to workers in order to attract them. However, in Section 5, the only lever that a firm possesses to generate more surplus is to release information that allows for the worker to be efficiently allocated in the second period. When the firms have a training decision, training is potentially another lever with which to create surplus. If the efficient level of training is such that it would drive the worker's training wage to the point where the worker's first period credit constraint binds, then there is a trade-off between providing more efficient training and transferring surplus to the firm to compensate for this training which might require the worker agreeing to an (inefficient) information disclosure policy that allows the firm to earn some additional second period rents.[21] Equivalently, Becker (1964) has argued that workers must pay for general human capital and credit constraints might therefore lead to underprovision; here we argue that agreeing to an information disclosure policy might be a second-best means of allowing

[21] Note that this paragraph highlights training for general human capital. Since disclosure policies that allow the firm to earn higher second period rents might also lead to retention levels which are, from the ex-post perspective when match realizations are realized, inefficiently high, they might also lead firms to provide more specific training. Empirically, therefore, one might observe "complentarities" between general and specific training, even though there is no technological link between them.

the worker to pay for training.

This discussion complements a literature on information frictions and training (for example Katz and Ziderman (1990), or Acemoglu and Pischke (1999) for an overview) which has typically, assumed that firms cannot commit to training policies, instead treating information frictions as exogenous. In these papers, exogenous information frictions allow the current employer to capture some return for general training and so lead to training provision. Here instead, we posit the reverse causality: training (when the worker is credit constrained and cannot pay for it) leads to worker to agree to information policies that allow the firm to earn a return on its training investment.[22]

Finally, we have, of course, taken a somewhat narrow view of organisational design, even given our exclusive focus on information management. In particular, we have abstracted from endogenous information acquisition; for example, through firms' decisions on the extent, nature and frequency of appraisal.[23] For the purposes of inducing adverse selection, acquiring more information with a fixed amount disclosed is akin to disclosing less with a fixed amount acquired. In other words, firms can manage information simply by getting to know their workers better. Skill augmenting and competitive firms will generally take a very different view. For competitive firms, information privately acquired about their worker's general human capital becomes a hot potato—something to be passed on to the market as quickly as possible. In contrast, for skill-augmenting firms, incentives to acquire private information about worker productivity are more nuanced and one would expect to see deliberate policies designed to generate such information. These differential incentives are likely to accentuate the increased wage inequality for skill-augmenting firms identified in the paper.

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[22] In the paragraphs above we have assumed that the firm can commit to training, but even when it cannot, workers will understand that firms' equilibrium training policies will depend on the information structure to the extent that these training policies influence the distribution of adverse selection.

[23] *Exogenous* changes in information acquisition were considered in Section 5.2.1, where we calculated the impact of a change in the variance of $R_K - G_K$ and G_K on labour turnover and the distribution of employment wages.

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Appendix

Proof of statement in Assumption 2. The statement is: $E[G_I|R_I = r]$, $r - E[G_I|R_I = r]$ and $E[G_I|R_I - G_I = r]$ are all increasing in r and, for any $w \in R$, $E[G_I|R_I \leq w] \leq E[G_I]$ and $E[G_I|R_I \geq w] \geq E[G_I]$. Let $S_I = R_I - G_I$ and denote the density of (S_I, G_I) as $f(s, g)$. The density of (R_I, G_I) is therefore $f(r - g, g)$ it follows that from affiliation and log concavity that both $f(s, g)$ and $f(g, r-g)$ are TP_2, i.e. both (S_I, G_I) and (R_I, G_I) are affiliated. This implies $E[G_I|R_I = r]$ and $E[R_I - G_I|R_I = r]$ are increasing in r as required. Also, for all w, $E[G_I|R_I \leq w] \leq E[G_I]$. ■

Proof of Proposition 3. By the law of iterated expectations

$$w_{T_I}(t) = E\left[G_I|T_I = t, R_I \leq w_{T_I}(t)\right] = E\left[E\left[G_I|T_I = t, R_I\right]|T_I = t, R_I \leq w_{T_I}(t)\right].$$

Using the regression equation

$$E\left[G_I|T_I = t, R_I\right] - \mu_G = \beta_{GT.R}\left(t - \mu_T\right) + \beta_{GR.T}R_I$$

and $\mu_T = 0$, we have

$$\begin{aligned} w_{T_I}(t) &= E\left[\mu_G + \beta_{GT.R}t + \beta_{GR.T}R_I|T_I = t, R_I \leq w_{T_I}(t)\right] \\ &= \mu_G + \beta_{GT.R}t + \beta_{GR.T}E\left[R_I|T_I = t, R_I \leq w_{T_I}(t)\right]. \end{aligned}$$

Since the conditional random variable has a normal distribution: $[R_I|T_I = t] \sim N\left(E[R_I|T_I = t], \sigma^2_{R|T}\right)$, we can write $[R_I|T_I = t]$ in terms of a standard normal random variable Z:

$$[R_I|T_I = t] \equiv E[R_I|T_I = t] + \sigma_{R|T}Z.$$

Using Z,

$$\begin{aligned} w_{T_I}(t) &= \mu_G + \beta_{GT.R}t + \beta_{GR.T}E\left[R_I|T_I = t, R_I \leq w_{T_I}(t)\right] \\ &= \mu_G + \beta_{GT.R}t + \beta_{GR.T}E[R_I|T_I = t] + \beta_{GR.T}\sigma_{R|T}E[Z|Z \leq \frac{w_{T_I}(t) - E[R_I|T_I = t]}{\sigma_{R|T}}]. \end{aligned}$$

Using the regression equation $E\left[R_I|T_I = t\right] - \mu_R = \beta_{RT}\left(t - \mu_T\right)$ and $\mu_R = 0$, we have

$$w_{T_I}(t) = \mu_G + t\left(\beta_{GT.R} + \beta_{GR.T}\beta_{RT}\right) + \beta_{GR.T}\sigma_{R|T}E[Z|Z \leq \frac{w_{T_I}(t) - E[R_I|T_I = t]}{\sigma_{R|T}}]$$

or using Cochrane's identity $\beta_{GT} = \beta_{GT.R} + \beta_{GR.T}\beta_{RT}$,

$$w_{T_I}(t) = E[G_I|T_I = t] + \beta_{GR.T}\sigma_{R|T}E[Z|Z \leq \frac{w_{T_I}(t) - E[R_I|T_I = t]}{\sigma_{R|T}}].$$

Noting that since $\phi'(x) = -x\phi(x)$,

$$\frac{\int_{-\infty}^{z}\phi'(x)dx}{\Phi(z)} = \frac{\phi(z)}{\Phi(z)} = \frac{\phi(-z)}{1-\Phi(-z)} = h(-z) = -\frac{\int_{-\infty}^{z}x\phi(x)dx}{\Phi(z)} = -E[Z|Z \leq z]$$

gives the required expression for $w_{T_I}(t)$. $\blacksquare$